NPS-AM-07-033

EXCERPT FROM THE

PROCEEDINGS

OF THE

FOURTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM THURSDAY SESSIONS

Applying Insights from Transaction Cost Economics (TCE) to Improve DoD Cost Estimation

by

Raymond (Chip) Franck, Senior Lecturer

Diana I. Angelis, Associate Professor

Francois Melese, PhD, Associate Professor, and

John Dillard, Senior Lecturer, Naval Postgraduate School

4th Annual Acquisition Research Symposium of the Naval Postgraduate School:

Acquisition Research: Creating Synergy for Informed Change

May 16-17, 2007

Approved for public release, distribution unlimited.

Prepared for: Naval Postgraduate School, Monterey, California 93943

Acquisition Research program
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

The research presented at the symposium was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

To request Defense Acquisition Research or to become a research sponsor, please contact:

NPS Acquisition Research Program
Attn: James B. Greene, RADM, USN, (Ret)
Acquisition Chair
Graduate School of Business and Public Policy
Naval Postgraduate School
555 Dyer Road, Room 332
Monterey, CA 93943-5103
Tel: (831) 656-2092
Fax: (831) 656-2253
E-mail: jbgreene@nps.edu

Copies of the Acquisition Sponsored Research Reports may be printed from our website www.acquisitionresearch.org

Conference Website:
www.researchsymposium.org

Proceedings of the Annual Acquisition Research Program

The following article is taken as an excerpt from the proceedings of the annual Acquisition Research Program. This annual event showcases the research projects funded through the Acquisition Research Program at the Graduate School of Business and Public Policy at the Naval Postgraduate School. Featuring keynote speakers, plenary panels, multiple panel sessions, a student research poster show and social events, the Annual Acquisition Research Symposium offers a candid environment where high-ranking Department of Defense (DoD) officials, industry officials, accomplished faculty and military students are encouraged to collaborate on finding applicable solutions to the challenges facing acquisition policies and processes within the DoD today. By jointly and publicly questioning the norms of industry and academia, the resulting research benefits from myriad perspectives and collaborations which can identify better solutions and practices in acquisition, contract, financial, logistics and program management.

For further information regarding the Acquisition Research Program, electronic copies of additional research, or to learn more about becoming a sponsor, please visit our program website at:

www.acquistionresearch.org

For further information on or to register for the next Acquisition Research Symposium during the third week of May, please visit our conference website at:

www.researchsymposium.org

THIS PAGE INTENTIONALLY LEFT BLANK

Applying Insights from Transaction Cost Economics (TCE) to Improve DoD Cost Estimation

---

Presenter: Raymond (Chip) Franck, PhD, Senior Lecturer, Graduate School of Business & Public Policy, Naval Postgraduate School, retired from the Air Force in 2000 in the grade of Brigadier General after thirty-three years commissioned service. He served in a number of operational tours as a bomber pilot; staff positions which included the Office of Secretary of Defense and Headquarters, Strategic Air Command; and was Professor and Head, Department of Economics and Geography at the US Air Force Academy. His institutional responsibilities at NPS have included the interim chairmanship of the newly-formed Systems Engineering Department from July 2002 to September 2004, teaching a variety of economics courses, and serving on a number of committees to revise curricula for both the Management and Systems Engineering disciplines. His research agenda has focused on defense acquisition practices and military innovation.

Author: Diana I. Angelis, Associate Professor, studied accounting at the University of Florida and received a B.S. in Business Administration in 1977 and a B.S. in Electrical Engineering in 1985. She received her Ph.D. in Industrial and Systems engineering from the University of Florida in 1996. Her research interests include cost accounting, activity-based costing, valuation of R&D and acquisition innovation. She was commissioned an officer in the United States Air Force in 1984 and served as a program engineer until 1989. Dr. Angelis is a Certified Public Accountant and a Lt Col in the US Air Force Reserve. She joined the DRMI faculty in 1996.

Author: Francois Melese, PhD, joined the NPS faculty in 1987. He earned his undergraduate degree in Economics at UC Berkeley, his Master's at the University of British Columbia in Canada, and his PhD at the Catholic University of Louvain in Belgium. After five years as a faculty member in the Business School at Auburn University, Francois joined NPS as part of the Defense Resources Management Institute (DRMI). In his time at NPS, he has taught public budgeting and defense management in over two dozen countries and has published over 50 articles and book chapters on a wide variety of topics. More recently, at the request of the State Department and NATO Headquarters, he has represented the US at NATO Defense meetings in Hungary, the Ukraine, Germany and Armenia. His latest article (co-authored with Jim Blandin and Sean O'Keefe) appeared in the *International Public Management Review*. The article (available at www.ipmr.net) is entitled "A New Management Model for Government: Integrating Activity-Based Costing, the Balanced Scorecard and Total Quality Management with the spirit of the Planning, Programming and Budgeting System."

Author: John Dillard joined the NPS faculty in the fall of 2000 with extensive experience in the field of systems acquisition management. His research focuses on defense acquisition policy changes and their implications. Dillard began his career in program and contract management after attaining a MS in Systems Management from the University of Southern California in 1985. He has been involved with myriad technologies and system concepts that have evolved into fielded products, such as the M-4 Carbine, 120mm Mortar, and M-24 Sniper Weapon. He was the Assistant Project Manager for Development of both the Army Tactical Missile System and, later, the JAVELIN Antitank Weapon System at Redstone Arsenal, Alabama. All of these systems incorporate state-of-the-art technologies, are in sustained production and fielding, and are now battle-proven. He was the Product Manager for the Joint Advanced Special Operations Radio System, and in 1998 was appointed to head Defense Department contract administration in the New York metropolitan area. Dillard has consulted for the governments of Mexico and the Czech Republic on achieving excellence in the public sector. As an adjunct professor for the University of California at Santa Cruz, he teaches courses in project management and leadership to Silicon Valley public- and private-industry professionals.

Raymond (Chip) Franck, Senior Lecturer
Graduate School of Business & Public Policy

Naval Postgraduate School
Monterey, CA 93943
Phone: (831) 656-3614
E-mail: refranck@nps.edu

Diana I. Angelis, Associate Professor
Defense Resources Management Institute
School of International Graduate Studies
Naval Postgraduate School
Monterey, CA 93943
Phone: (831) 656-2051
E-mail: diangeli@nps.edu

Francois Melese, PhD, Associate Professor
Defense Resources Management Institute
School of International Graduate Studies
Naval Postgraduate School
Monterey, CA 93943
Phone: (831) 656-2009
E-mail: fmelese@nps.edu

John Dillard, Senior Lecturer
Graduate School of Business & Public Policy
Naval Postgraduate School
Monterey, CA 93943-5197
Phone: (831) 656-2650
E-mail: jtdillard@nps.edu

I. Introduction

There is mounting evidence of a systematic bias in initial cost estimates of new weapon systems. A comprehensive 2006 RAND report on major weapons programs concludes: "[The] analysis indicates a systematic bias toward underestimating the costs […] of a weapon system." (Arena 2006, p.1). This bias could threaten our national security. Unrealistically low cost estimates result in cost overruns. Fixing cost overruns can impact military readiness.

Two factors are usually blamed for unrealistically low cost forecasts: bad incentives (psychological and political-economic explanations) and bad estimates (methodological explanations). The focus of this study is on cost methodology. Our goal is to contribute some new ideas to the current literature on cost estimating. This paper applies Transaction Cost Economics (TCE) (e.g., Williamson, 1985; Dillard, Franck & Melese, 2006) to help characterize, explain, and ultimately reduce the cost growth that plagues many of today's major investments in military capabilities.

In business, two costs are typically factored into the "make-or-buy" decision: production costs and the costs of managing transactions—"transaction costs" (Coase 1937). Conventional estimation techniques tend to focus on production costs (input costs, learning curves, economies of scale and scope, etc.). TCE emphasizes another set of costs—primarily the costs of coordination and motivation (e.g., search and information costs, decision and contracting costs, monitoring and enforcement costs). The primary insight drawn from TCE is that correctly estimating the economic production costs of an acquisition is necessary, but not sufficient. The choice of contract, organization, and incentives, along with key characteristics of markets and transactions (uncertainty, complexity, asset specificity, frequency, and contestability), must be included to obtain reliable cost estimates.

II. Background

A recent Government Accountability Office (GAO) study cites multiple examples of weapon systems cost increases. The GAO reports significant unit procurement cost increases for several familiar programs. The Joint Strike Fighter saw unit procurement costs increase over 25%, the Army's Future Combat Systems over 50%, while the Air Force's F-22A Raptor experienced almost 200% procurement cost overruns (GAO April 2006, p.5). According to another GAO report, "[p]rograms consistently move forward with unrealistic cost […] estimates" (GAO Mar 2006, p.1).

Traditional cost estimating relies on a Work Breakdown Structure (WBS). Similar to an economist's production function, a WBS captures the mix of inputs and activities required to produce a specific weapon system. Cost estimates developed for each component of the WBS are rolled up into an overall estimate for the project. Also, simulation methods can be used to capture uncertainty and provide a distribution of possible weapon system costs. Confidence intervals applied to this distribution allow cost estimators to report probabilities associated with specific ranges of costs for a particular weapon system. However, the confidence in these cost estimates depends *inter alia* on the completeness of the model. TCE offers complementary considerations that can impact the costs of major weapon systems, many of which are known but not explicitly factored into traditional cost estimates.

In its recent review of the literature, a RAND study reports, "our analysis […] shows that, by and large, the DoD and military departments have underestimated the cost of buying new weapon systems" (Arena, 2006). Virtually all the studies that RAND examined found a systematic downward bias in cost estimates. The average cost growth over initial forecasts of weapon systems in the development phase ranged from 16 to 26%. Estimates of procurement cost growth averaged between 16% and 65%, while total weapon program cost overruns averaged between 20 to 54%.

Cost estimates serve two main functions. First, they serve as an integral part of the decision process (cost-benefit or "analysis of alternatives") used to evaluate military investments. Second, they provide the foundation for future defense budgets.

In the first case, underestimating costs can result in overestimates of the affordable quantity of those weapons. It can, therefore, result in too many new weapon program starts and excessive investments in those systems. In the second and related case, unrealistically low cost estimates result in overly optimistic budgets. Budgets planned on the basis of optimistic cost estimates create the illusion of more resources available than actually exist. Since acquisition budgets are, in essence, a contract for major weapon systems between the DoD and Congress, unrealistic cost estimates can lead to a breach of trust and can poison relations between the branches of government.

One method used to cope with cost overruns is to stretch out programs and cut quantities that reach the force. But this sacrifices both current and future operational capability. Moreover, spreading fixed costs over fewer units increases unit production costs. The end result can be to get less (quantity) for more (money). Another method to pay for cost overruns is finding savings in training, operations, and maintenance budgets. But this also risks sacrificing current and future operational capability. Reprogramming money from other programs to accommodate cost increases is another approach. But this is a limited remedy (constrained to no more than $10M in RDT&E and $20M in Procurement within a program element) and can have a negative and cascading effect on other programs' costs, schedules, and performance. The net effect of cost overruns is clear. Short of a bailout from Congress, systematically underestimating costs reduces the overall readiness and availability of military forces and equipment.

III. Alternative Explanations of Unrealistic Cost Estimates

The two factors commonly used to explain "unrealistic cost estimates" are bad incentives [due to optimism bias (psychological explanation), or perverse bureaucratic incentives and strategic misrepresentation of budgets (political-economic explanation)], and bad estimates [imperfect forecasting techniques such as an omitted variable bias (methodological explanation)]. It is helpful to examine these factors in the context of the Planning, Programming, Budgeting and Execution (PPBE) process used by the DoD to build the nation's defense budget.

In theory, "Programming" involves a constrained optimization in which investment and operating decisions are made to maximize national security subject to fiscal constraints. The Secretary of Defense (including OSD Program Analysis and Evaluation (PA&E) and the DoD Comptroller) and the Chairman of the Joint Chiefs of Staff have good reasons to prefer accurate cost estimates given their global optimization perspective.

In contrast, given their sub-optimizing perspectives, Combatant Commanders and the Military Services (for instance) may be more subject to a bias toward optimism and to perverse bureaucratic incentives. Since their primary focus is on performance and military capability, they have reason to be less critical (and realistic) in their cost estimates.

According to McNicol (2005, p. S-4), "statistical analysis is consistent with the well-established presumption that the military services tend to prefer […] optimistic procurement cost estimates." Program Element Monitors (PEMs), for example, act as advocates for the funding of their programs and are responsible for defending those programs throughout the PPBE cycle. Since all programs compete for the DoD's limited resources in a particular funding categories, PEMs are well aware that resource allocation is a competitive, constant-sum game. Given their job descriptions, PEMs are drawn to lower cost estimates that fit their advocacy agendas, rather than to higher cost estimates which make defending their programs more difficult. Moreover, since they do not always posses a higher-level perspective, they may not fully appreciate how underestimating costs can impact other programs.

Also, defense companies have good reasons to strategically underestimate costs since this makes their programs more attractive to the DoD and the Congress. Here, the logic can be interpreted by leveraging one of the hallmarks of TCE, the "fundamental transformation" (Williamson, 1996). The standard example is when *ex ante* competitive bidding leads to an *ex post* bilateral monopoly situation. The risk is that the winning supplier can lock in the Government by making investments in productive assets that are specific to the relationship (and that have little value outside the relationship). Once the DoD "buys in," defense firms can lock in their customer by investing in specific assets (e.g., production facilities) that act as barriers to entry. While initially advantageous, such investments in specific assets can make it prohibitively costly for other companies to compete in subsequent re-bidding of the contract.

Given the complexity and uncertainty of many major, technologically advanced weapon systems, contracts are necessarily incomplete; i.e., they cannot cover all possible contingencies. As a consequence, the incumbent company can be confident it will recoup overruns from multiple change-orders (generally for added scope) anticipated over the life of the contract. In fact, firms have an incentive to anticipate, but strategically omit, some of these elements in the original contract negotiation. Moreover, by strategically hiring workers in key Congressional districts, the company can pressure Congress to retain the contract and approve compensation for cost overruns to preserve jobs. This combination of strategic behaviors could explain some of the systematic bias in initial cost estimates.

Therefore, cost-estimating techniques must properly anticipate transaction costs such as measurement, monitoring, management and re-negotiation costs that can quickly overwhelm initial production cost estimates, and which vary according to the nature of the transaction. If TCE considerations are not properly anticipated, the result will be that cost-estimators will continue their downward bias, and programs will continue to suffer cost overruns. One possible means to improve DoD cost estimation is to add transaction cost considerations to the current production cost focus in cost-estimating methods.

In an early attempt to address the factors that lead to biased cost estimates, Secretary of Defense Melvin Laird directed that independent parametric cost estimating be made a part of the DoD acquisition process. The Office of the Secretary of Defense (OSD) launched an independent Cost Analysis Improvement Group (CAIG) that began operations in the Spring of 1972. Eventually, the CAIG was assigned the statutory responsibility of providing independent lifecycle cost estimates for all major weapon acquisition programs. According to McNicol (2005), “the introduction of independent parametric costing […] had a major, continuing effect on reducing procurement cost growth” (p.44).

Whereas independent cost estimation is an important step that clearly attenuates the impact of psychological and political-economic factors, the challenge of developing a more comprehensive cost estimating/forecasting methodology remains. Hence, the primary focus of this study is to leverage insights from TCE to improve the DoD’s cost estimating/forecasting methodology—while recognizing those other causes of bias in cost estimates.

The next section (IV) reviews traditional cost estimating. The following section (V) reviews some key contributions of Transaction Cost Economics. Section VI introduces two sets of hypotheses relating to DoD cost estimating and describes how insights from TCE might be leveraged to improve DoD cost estimation. The following section (VII) of the paper offers two case studies interpreted in the context of TCE. Section VIII reports our search for evidence of transaction costs found within program office budgets and its results. The concluding section (IX) offers some policy recommendations to improve future DoD cost estimating/forecasting.

IV. A Brief Review of Cost Estimating in the Department of Defense

In the defense acquisition process, a cost estimate is a prediction or forecast of the cost of a program or weapon system. *DoD Instruction 5000.2* requires that both a program office estimate and a DoD component cost-analysis estimate be prepared in support of acquisition milestone reviews. For major defense acquisition programs, these estimates are subject to review by the OSD Cost Analysis Improvement Group (CAIG). In addition, the CAIG performs an independent lifecycle cost estimate for all ACAT ID programs and for certain ACAT IC programs.[1]

The first step in any cost estimate is to understand the attributes of the program or weapon system whose cost is to be estimated. Traditionally, this requires understanding and describing the weapon system in terms of physical and technical parameters, operational and support concepts, mission requirements, and interfaces with other systems. Understanding the program's schedule and acquisition profile is also important in developing a cost estimate. The goal is to understand the relationship between key weapon system attributes and cost. For programs reviewed by the CAIG, this first step is documented in the Cost Analysis Requirements Description (CARD), according to the guidelines in *DoD 5000.4-M.*

The second step is to develop an explicit framework for the cost estimate. The Work Breakdown Structure (WBS) is a hierarchy of weapon system components (hardware, software, data, facilities, and services) that attempts to capture economic production cost elements of the estimate. A WBS is developed by subdividing a product, process or service into its major work elements and sub-elements. The highest level, the system WBS, can be organized according to the lifecycle phases of a system: Research & Development, Investment, Operating and Support and Disposal.

Under each phase, a hierarchical structure documents the activities and resources required to complete the work associated with that phase. Under the Investment phase, for example, the Program WBS encompasses the entire acquisition program, including production costs derived from the Contract WBS. This defines at an aggregated level what is to be procured and consists of at least three program levels with associated definitions.

The Program WBS is used by the Government program manager and contractor to develop and extend a Contract WBS. It contains uniform terminology, definitions, and placement in the input-oriented family tree structure. The contract WBS provides the structure for information contained in the Contractor Cost Data Reporting System and other cost performance reports and is defined by *Military Handbook 881A*. Operating and Support costs are organized in a Cost Element Structure in accordance with CAIG guidance, similar to the way the WBS is used to organize development or production costs. An example of a program WBS is shown in Figure 1.

---

[1] Acquisition Category (ACAT) I is defined by *DODI 5000.2* as a major defense acquisition program (MDAP) that either has a dollar value estimated by the USD(AT&L) to require an eventual total expenditure for research, development, test and evaluation (RDT&E) of more than $365 million in fiscal year (FY) 2000 constant dollars or, for procurement, of more than $2.190 billion in FY 2000 constant dollars, or has been designated of special interest by the Milestone Decision Authority (MDA). (DODI 5000.2, enclosure 2)

The level of detail in the WBS evolves as the system is defined and developed throughout its lifecycle. After the program WBS has been approved, the contractor will then extend the contract WBS to the appropriate lower levels to better define the complete scope of the contract. When integrated with the program WBS, the extended contract provides a complete WBS for the acquisition program. Similar to the economists' production function, the WBS reveals all the key inputs required to generate the ultimate output/product.

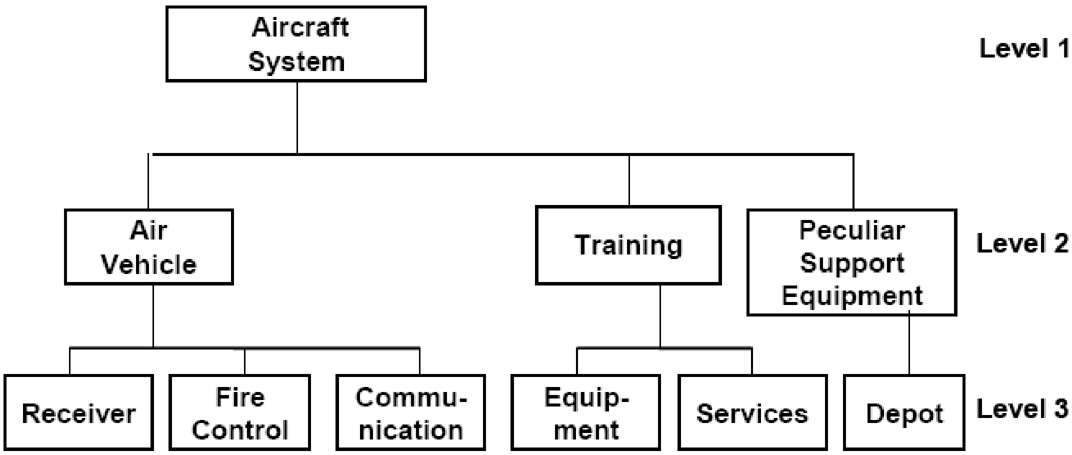

Figure 1. Program WBS
(DoD, 2005)

The next step is to develop a cost estimate. From the WBS perspective, the total cost of the system is obtained by adding up the cost of the individual elements (inputs) in the hierarchy across the levels of the WBS. In order to do this, a cost estimate must be generated for each element of the WBS. The level of detail of the cost estimate depends on the amount of information available about the system. In the early stages of development, there are only rough estimates of the system parameters/attributes; therefore, only the highest levels of the WBS cost can be estimated using "rough order of magnitude" or "top-down" techniques such as analogy and parametric or cost estimating relationships (Blanchard, p. 595). For example, the estimated cost of a new aircraft may be modeled as a function of the weapon system's key inputs/attributes like empty weight, speed, useful load, wing area, power, and landing speed. This model estimates the total cost of the aircraft based on a set of parameters independent of the WBS structure.

As more information about the system becomes available, more detailed estimates can be developed for lower levels of the WBS using a variety of techniques. A cost estimate is now developed for each element at a given level of the WBS. For example, the cost of the aircraft wing may be estimated using historical data for weight, area, and materials. While this estimate is still based on the parametric technique, the level of detail (a wing) corresponds to a WBS element. As the system matures, the work and resource requirements are sufficiently well defined to use "bottoms up" techniques such as engineering estimates and actual costs obtained from prototypes and early production models. An engineering (production function) estimate would be based on the labor, material and overhead required to complete a particular element of the WBS. Obviously, this sort of estimation requires a great deal of information about how the system is built—data that is usually not available until the early phases of production. Figure 2 shows the relationship between estimating techniques and the evolution of a system.

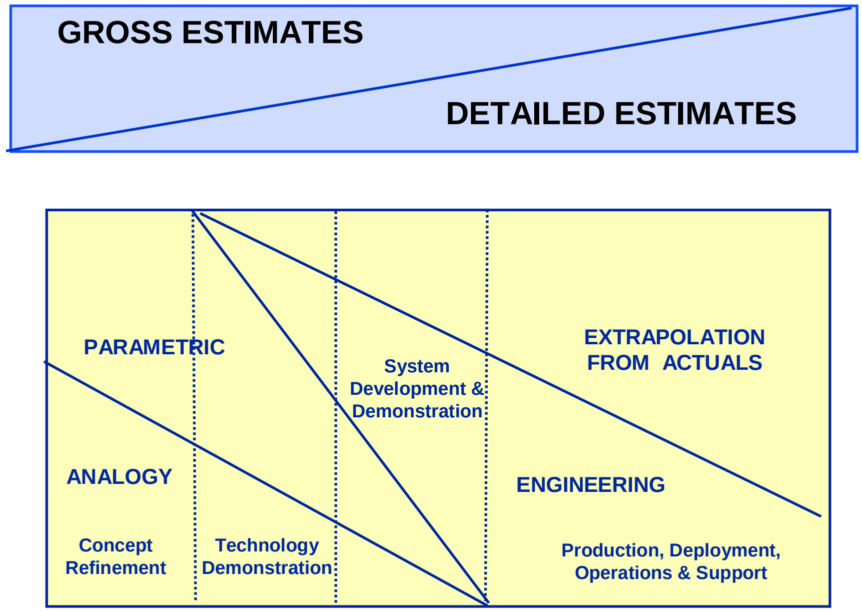

Figure 2. Cost Estimating Techniques as a Function of Acquisition Phases

While the WBS framework provides an excellent accounting system for cost estimates, it does have a few drawbacks. First, although it does capture the functional relationship between inputs/elements, it does not explicitly show the correlation between cost elements. If there is a correlation between cost elements that are assumed independent, this can significantly increase the variability of the cost estimate. Second, the program WBS, as defined by *Military Handbook 881A* , is input-oriented, not relationship-oriented; it, therefore, largely overlooks transaction costs such as search and information costs, decision and contracting costs, monitoring and enforcement costs. While it might be argued these costs are implicitly considered in the cost estimates of the various WBS components, it is likely that most are either underestimated or ignored, resulting in overly optimistic cost estimates.

V. A Brief Review of Transaction Cost Economics (TCE)

Transaction costs are typically faced by organizations dealing with outside suppliers. These include costs associated with: source selection, periodic competition and renegotiation, contract management, market structure, and measuring and monitoring performance. TCE emphasizes four key characteristics of transactions: *complexity*, *uncertainty*, *frequency*, and *asset specificity*. Transaction Cost Economics offers an attractive theoretical foundation for competitive sourcing decisions in the private sector (e.g., Coase, 1937; Williamson, 1971; 1979; Alchian & Demsetz, 1972). However, TCE has been less often applied in a government setting (e.g., Pint & Baldwin, 1997; Williamson, 1999; Franck & Melese, 2005; Dillard, Franck & Melese, 2006). An underlying objective of TCE (as a field of inquiry) is to improve the design of contracts, organizations, and other governance structures that reduce transaction costs and improve the gains from exchange between buyers and sellers.

TCE predicts parties involved in a defense transaction can benefit from cooperation in the buyer-seller relationship and, thereby, generate a surplus that can be shared. For example, specific investments[2] made by either party that are of real value in the relationship (but perhaps of lesser value outside the relationship), can improve efficiency and effectiveness—yielding a surplus to be shared between the two parties. However, those parties often have conflicting interests; the DoD wants to maximize defense capabilities subject to budget constraints while Industry must concern itself with profits. Therefore, both sides have incentives to behave opportunistically, and may not necessarily have sufficient motivation to make investments that increase the parties' total gains. This is particularly true when specific assets are involved and information is imperfect and asymmetric. While defense acquisition focuses on production costs, it also exposes the organization to costs of managing the outsourcing relationship and to the risks of bad (opportunistic) behavior on the part of contracting partners.

Relationship-specific investments are potentially valuable, but can increase risks to both parties in a transaction. Having made a specialized investment, the supplier becomes the most efficient provider, and thus has an incentive to look for opportunities to extract more of the surplus (perhaps by demanding large increases in contract price to execute change orders). If a customer is "locked in," they may have little recourse. At some point, the relationship is transformed from a customer having the choice of a number of competing suppliers to a bi-lateral monopoly relationship between a single buyer and single seller. At this point, close-in bilateral bargaining replaces the impersonal (arms'-length) arrangements of the competitive marketplace.

This entails a *basic transformation* of the supplier from competitive bidder (prior to source selection) to monopoly supplier (after source selection), especially if there are no close substitutes for this particular contractor's products. Accordingly, the customer is now vulnerable to "opportunistic behavior"[3] from the contractor. Unforeseen circumstances combined with newly inelastic demand may prompt the supplier to extract more of the surplus created in the relationship.[4] The supplier can exploit its power in the relationship to renegotiate the basic agreement to its advantage, otherwise threatening to dissolve the agreement. The TCE literature refers to this as a "hold up."[5] This is one of the key insights TCE can offer to improve initial cost estimating.

If the supplier makes specific investments in assets that are only valuable in the context of the relationship with a specific customer, it is vulnerable to any changes in demand from that customer. Whereas relation-specific investments can increase the total gains from the defense

---

[2] Asset specificity comes in a variety of forms, such as human, location and physical. These are specialized assets that generate high returns within a specific relationship, but offer little value outside it.

[3] Williamson, 1996, defines "opportunism" as "self-interest seeking with guile"

[4] Besanko, Williamson and others have labeled the transition from one prospective buyer and many sellers to one buyer and one seller, from competitive market to a one-on-one relationship, as the "fundamental transformation." This transformation occurs, at least to a certain extent, after the completion of every source-selection process.

[5] According to Besanko, "a hold up problem arises when a party in a contractual arrangement exploits the other party's vulnerability due to relationship-specific assets."

acquisition, they also increase risks of opportunistic behavior, through which either party can hold up the other. For example, either party can hold up the other by threatening to change the terms of the contract (relationship). The danger is that if neither party feels like it can recover the full costs of its investment in the relationship/transaction (say through a continuation or renewal of the contract), then efficiency-generating specific investments will not be made, resulting in higher (unanticipated) costs.[6]

A crucial insight of TCE is that different *ex ante* contracts offer different incentives for unproductive ex post bargaining and influence activities. As in game theory, it helps to look forward and reason back. If it appears managing the contract (including future competitions and/or renegotiations), and evaluating and monitoring performance, are likely to be costly (in terms of dollars or disputes, see Pigeon, 2006), then this should be taken into account in the original cost estimate, as well as in negotiating the optimal contract type. Table 1 provides a simple illustration of the spectrum of contract types that were awarded to the top 10 defense contractors over a six-year period.

Category	Cost-Plus (C+)	Fixed-Price (FP)	Time & Materials
1. Lockheed Martin	50%	47%	2%
2. Boeing Co.	27%	70%	2%
3. Raytheon Co.	38%	58%	3%
4. Northrop Grumman	42%	50%	2%
5. General Dynamics	39%	60%	0%
6. SAIC	52%	21%	15%
7. Carlyle Group	44%	46%	9%
8. Newport News Ship	78%	22%	0%
9. TRW	71%	23%	2%
10. Computer Sciences	41%	26%	24%

Table 1. Unclassified Details on the Type of Contracts Won by the Top 10 Contractors on Items Outsourced from 1998 to 2003 (Percent of Contracts Awarded that Were Cost-plus, Fixed-price and Time & Materials) (Makison, 2004)

[6] Scope for opportunistic behavior may lead to adverse selection, choice of an (ex ante) inferior option (or technology), or moral hazard. Such scope increases risk that if a relationship-specific investment is made, the other party will exploit the terms of the contract to "hold them up." For example, changes in specifications are frequently used by contractors as a reason to raise prices and profits under government contracts, especially when those investments by the contractor create barriers to the entry of competitors.

The more complex and uncertain the transaction, the less complete the statement of work (performance work statement (PWS)), then the greater the cost in using FP, and the more attractive other contracting options become.[7] If the statement of work (PWS) describing the desired product, service or project can be specified precisely (IFB), and there are no transaction-specific assets involved, then FP type contracts have the benefit of creating cost-reducing incentives that reward the buyer through ex ante competition between potential suppliers. In this case, FP contracting increases contractor incentives to invest in cost reduction, and ex ante competition can transfer these cost-savings directly to the buyer.

In contrast, if the statement of work (PWS) cannot be specified precisely (RFP) or if there are significant specific assets involved in the transaction, then some surplus will be eroded by the frictions of ex post re-negotiation. This loss from unproductive bargaining activity is part of the cost of using a FP contract in this case. Initial cost estimates must take this into account.

Evidence uncovered by Bajari and Tadelis (1999) reveals that in cases in which a transaction is easy to define and measure (i.e., there is little complexity), and only a few minor changes are expected (i.e., there is little uncertainty), FP-type contracts tend to dominate. However, the more complex the transaction—the more difficult/costly it is to define and measure performance, and the more uncertain—the more likely it is a change in the contract will be required, the more severe the adversarial relationships experienced ex post when FP contracts are chosen. In the latter case, FP-type construction contracts often ended in costly renegotiations in which any surplus generated was dissipated in the course of those negotiations through unproductive bargaining and influence activities. Thus, *complexity* and *uncertainty* can force parties to turn away from FP type contracts and towards C+ type contracts, and to rely heavily on reputation and other enforcement mechanisms to avoid ex post opportunistic behavior that threatens to dissipate the surplus generated by a transaction.

FP (C+)-type contracts are usually prescribed in later (earlier) stages of product development when complexity and uncertainty have (have not) been resolved, and the performance work statement is well (not well) defined. Note that while these prescribed contracts focus on the characteristics of *complexity* and *uncertainty*, apparently overlooked are the vital roles of *frequency* and *asset specificity*—two key components of TCE.

In the case of *frequency*, recurrent transactions often justify the setup costs of specialized assets and special governance requirements. They also offer the opportunity to apply learning curves (cumulative cost-quantity relationships) to lower production costs, and for gradual reductions in uncertainty as both parties learn more about costs. Recurring transactions also offer the possibility for the accumulation of goodwill and to build reputations. Strategic partnerships and relation-specific investments can increase the benefits to both parties, but they

---

[7] An example of the latter is Performance-based Logistics (PBL). The DoD defines PBL as: "an integrated acquisition and sustainment strategy for enhancing weapon system capability and readiness, where the contractual mechanisms […] include long-term relationships and appropriately structured incentives with service providers, both organic and non-organic [to] support the end user's (warfighter's) objectives." Any future investments in PBL could benefit from the multiple insights generated by TCE. The decision to outsource weapon system support or to bundle that support with an acquisition and to outsource the resulting bundle should weigh production cost savings against the costs and risks associated with a critical source of supply being outside the DoD's control. Those costs and risks are part of the transaction costs of outsourcing. TCE indicates outsourcing should only occur if there are positive net savings from the external supply relationship.

also leave them vulnerable to opportunistic behavior, or a hold up, by the other party. These vulnerabilities can be overcome with well-crafted contracts. However, contracting (a) involves an expenditure of resources, and (b) cannot eliminate all risks associated with opportunistic behavior from partners in the transaction.[8]

The interaction of opportunism with imperfect and asymmetric information raises the possibility of unproductive bargaining/influence or rent-seeking activities.[9] The ultimate outcome—a balance of productive efforts and unproductive bargaining—depends on the characteristics of the transaction, and the incentive structures that govern the parties involved, both of which should be factored into initial cost estimates.[10]

Where a transaction requires little in the way of specific assets (no hold up problem), and involves a product or service that is a) well-defined and homogeneous (IFB), b) easy to measure (limited complexity and mild information asymmetry), c) routinely used (recurring/frequent purchases), d) not subject to change (limited demand uncertainty), and e) is offered by competing suppliers, then there is little room for negotiation (price and performance are market-driven), and the marginal benefit of unproductive bargaining is near zero. With little room for bargaining over such routine and uncomplicated transactions, substantial production and transaction cost stability can be expected in the defense acquisition. Moreover, since administrative, incentive, and enforcement costs tend to be low for acquisitions in more contestable (competitive) markets, the marginal cost of engaging in the transaction is smaller for the DoD, and there exists an incentive for the supplier to invest in the transaction which generates opportunities for cost savings.

In general, the less complex and uncertain a transaction, the easier it is to write an explicit contract that covers all relevant contingencies. Moreover, the lower the administrative and enforcement costs of that contract, the lower the transaction costs associated with the contract. These favorable characteristics should encourage greater productive effort in the transaction relationship that, in turn, should contribute to lower costs and better products that benefit both parties. Identifying and understanding the characteristics of the transaction could result in more accurate initial cost estimates.

---

[8] Costs associated with contracting and the holdup risks remaining are major components of "transactions costs." The process of contracting includes drafting the relevant documents, negotiating a version of the contract that is signed, taking actions to enforce that contract, and renegotiating when needed. These tasks entail, at minimum, the services of skilled people who develop local knowledge of the specific business relationship. There may also be costs associated with litigation, to include both direct (e.g., monetary) and indirect (e.g., time delay) components. Furthermore, the basic contract may well need considerable administrative and management attention throughout its life, even if full-scale renegotiation is not undertaken. Accomplishing these tasks satisfactorily involves expenditure of resources and management attention. Transaction costs (source selection, contract management and performance monitoring) can negate a significant portion of the production cost savings involved with outsourcing.

[9] The concept of unproductive bargaining and rent-seeking is usually attributed to Tullock (1971; 1993), Krueger (1974), and Bhagwati (1980). A key insight of this literature is that costly bilateral bargaining by two parties for a bigger share of the surplus they jointly create can dissipate or even eliminate that surplus (Tullock, 1971).

[10] There are other factors as well. For example, Wolff and Reed (2000) find significant evidence that, *inter alia*, the nature of, and access to, assets in a joint venture are important in predicting the balance of positive sum (productive) and zero sum (unproductive) outcomes for the participants.

Alternatively, transactions that involve a non-standard (less homogeneous or highly differentiated) product often take place in a bilateral monopoly contractual setting. In this case, assuming no specific assets are required, the results depend on the degree of contractual ambiguity governing the transaction, as well as on any administrative and enforcement costs involved. However, as complexity, uncertainty, and opportunism due to specific investments increase, so does the marginal benefit of bargaining or ex post renegotiation. This results in both higher transaction costs to measure, monitor, and govern the relationship, as well as an increased risk of holdup.

Productive investment (or effort) involves two types of assets: general and specific. The greater the ratio of specific assets to total investments required in the relationship, the greater the risk of “holdup.” Moreover, as the threat of bilateral dependency increases, the more incomplete the contract (and the lower the penalty for reneging or renegotiation), the lower the marginal cost to each party of engaging in unproductive bargaining or renegotiation.

In the face of incomplete contracting, the holdup problem poses a hazard called “maladaptation.” The risk of maladaptation is captured here as an increase in the return to unproductive bargaining (for example, charging high prices for any change orders) or strategic renegotiation, both of which will increase costs from initial estimates. Any time ex ante competition among suppliers is transformed into an ex post, bilaterally dependent relationship, additional governance structures may be required to induce cooperative adaptation.[11] The challenge is to write a contract with enough precision to encourage desired performance, but enough flexibility to allow productive adaptation (adjustments), as circumstances require. But in the case of complex transactions and uncertain outcomes, “bounded rationality” precludes comprehensive ex ante contracting (contracts are inherently incomplete) which raises the possibility of gains from (unproductive) ex post opportunistic renegotiation (e.g., the “holdup” problem). Ideally, contracts can be written that specify measures of performance, conflict resolution procedures, and conditions under which the contract can be modified, as well as provisions for sharing gains from transaction-specific investments.[12]

In reality, contracting offers an imperfect solution to opportunism. Additional governance mechanisms to settle disputes and adapt to new conditions, ex ante efforts to screen for reliability, and provisions to protect transaction-specific investments may well ameliorate these problems. However, governance isn’t costless, and such agreements often increase external transaction costs; and factoring those considerations into initial cost estimates may well improve their accuracy.

Ashley & Workman (1986) caution that providing cost incentives in a contract can lead to disagreements and spoiled relationships and ex post friction in interpreting the outcomes. In

[11] According to Williamson & Masten (1999), the “central problem of economic organization is adaptation” (p.xi). The challenge of adaptation is especially acute when ex ante competition leads to ex-post monopoly power. Whenever products, services or projects cannot be well specified in advance (due to complexity, uncertainty about future conditions, measurement difficulties, etc.), and they involve transaction-specific assets, then ex ante competition (e.g. competitive bidding) can lead to ex-post monopoly/monopsony power. In turn, this leads to costly adaptation through bilateral bargaining and renegotiation.

[12] The implications of this paper suggest that in the case of out-sourcing a transaction in which complexity, uncertainty and asset specificity can lead to renegotiation, the choice of governance structure will drive productive effort and unproductive bargaining.

fact, avoiding these frictions and reducing the advantages to renegotiation can be accomplished by investing in a more complete PWS, and by adopting alternative mechanisms (e.g., reputation effects, GOCO[13]) to reduce the return from opportunistic behavior. TCE suggests that the degree of completeness of the PWS and the contract is an optimizing decision by both parties that reflects their trade-offs between an ex ante investment in the PWS and contract design, and the potential ex post cost of opportunistic renegotiation.

A principal insight of TCE is that the choice of optimal governance structure depends on the characteristics of the transaction. Understanding these characteristics can improve initial cost estimates by: a) sorting transactions into categories based on their principal characteristics (uncertainty, complexity, asset specificity, contestability and frequency), and b) recognizing the costs and consequences of alternative contracts, organizational structures and mechanisms that are used to govern those transactions.

VI. Hypotheses: Possible Contributions of TCE

Our basic hypothesis is that including TCE considerations (currently an omitted variable) can improve cost-estimation methodology by (a) helping to explain the systematic bias observed in initial cost estimates, and (b) increasing the general explanatory power of cost estimations. That is, we assert the traditional WBS approach may overlook some important variables, resulting in initial cost estimates that are (a) not accurate and (b) biased toward being unrealistically low. More specifically, the TCE perspective suggests the traditional WBS approach indeed overlooks two important variables: Coordination Costs and Motivation Costs. Unlike the production function approach of WBS, the TCE approach focuses on these and other key components of major weapon system acquisitions.

However, once production starts, the contractor acquires specialized information and assets. Production is often subject to economies of scale and learning curves. The ability to shop around becomes restricted. Even though there may be contestability in the original design/development stage, bi-lateral monopoly arrangements emerge.

The system program office's functions/activities related to monitoring, controlling, information-gathering, reporting, decision reviews, enforcement, etc., grow as oversight/governance increases with anticipated scale and risk of investments. Though program cost data may exist, it does not tell us the whole story on transaction costs. Ideally, we would want to find total program costs and contract costs. The difference consists of transaction costs (whose main components are coordination and motivation costs).

Coordination Costs include: i) Search and Information Costs—to identify options and acquire timely, accurate and relevant information to evaluate alternatives; ii) Bargaining and Decision Costs—to choose an alternative and negotiate and write a contract; and iii) Policing and Enforcement Costs—to make payments and measure, monitor, and evaluate performance.

Motivation Costs include: i) Costs to promote productive effort and incentives to encourage investment (better, faster, cheaper) and ii) Costs to deter unproductive bargaining, and opportunistic behavior (renegotiation). Factoring TCE cost considerations into cost-

[13] GOCO means "Government Owned, Contractor Operated" production assets.

estimating efforts could help the DoD anticipate cost increases in four key areas the GAO suggests help explain cost overruns:

a) constantly changing missions (uncertain demand/quantity/characteristics, bi-lateral monopoly, asset specificity, holdup, incomplete contracting);

b) yearly incremental funding vs. multi-year appropriations (uncertainty, frequency, asset specificity, holdup); program instability tends to discourage the investments that play a predominant role in moving costs down the learning curve (McNicol, 2005, p.26).

c) incentive problems (incomplete contracting, asset specificity, holdup); and

d) insufficient oversight (measurement, monitoring costs). (GAO, 1997)

A. Our Hypotheses in More Detail

The primary focus of this study is to see if insights from TCE can improve DoD cost-estimation/forecasting techniques. Our inquiry can conceptually be divided into three questions:

1. Is cost growth a problem?

   Ho: C $\equiv$ Mean Cost Growth Factor = Actual Cost/Forecast Cost = 1

   H_1: C > 1

2. Can cost-estimating models which include TCE insights improve estimated/forecast costs?

   Ho: TCE Factors (Complexity, Uncertainty, Asset Specificity, Frequency, etc.) do not matter—not significant in explaining cost growth.

   Ha: Alternatively, Forecast Cost = f (Production Costs; **Transaction Costs**), where Production Costs = g (WBS + systems integration),

   Transaction Costs = **Coordination Costs** + **Motivation Costs,**

   Coordination Costs = g (Market Contestability Structure; Asset Specificity; Frequency; Search & Information tasks, Contracting & Enforcement functions, needed Management & Monitoring)

   Motivation Costs = h (Complexity; Uncertainty [of various kinds], Contract Type ...)

There is a fair amount of evidence about these hypotheses extant. In a sample of 52 systems, the GAO found that RDT&E costs for programs that started development with mature technologies (low complexity/uncertainty) increased by a modest average of around 5%, while those with immature technologies (high complexity/uncertainty) experience cost growth on average of almost 35%. Similarly, unit costs of procurement rose by less than 1% for programs with mature technology, whereas programs that started with immature technologies saw increases in unit costs of nearly 27% over initial estimates. As predicted by TCE, Complexity and Uncertainty combine to increase contractual hazards. If this is not adequately addressed in the contracting phase, then there is a greater likelihood of cost overruns.

B. The Case for the Null Hypotheses

Broadly stated, the null hypotheses state that incorporating TCE considerations into cost estimates will not significantly improve cost-estimating methodology. In the course of our research, we found a surprisingly persuasive case in favor of that proposition. There are, in fact, a number of reasons to be skeptical about our claim that transactions cost factors are important in determining costs of major acquisition programs. A number of plausible assertions (some related, some mutually exclusive) underlay such skepticism. While we find these assertions unpersuasive on balance, we cannot dismiss them out of hand.

1. *Asymetric Scope for Opportunistic Behavior in Defense Transactions*: It is more difficult to behave opportunistically when involved in a business relationship with a sovereign entity. In that case, the government has more scope for opportunistic behavior, with more of the attendant costs falling on the contractors. And, since the cost estimates we're considering refer primarily to the government's cost, adding TCE considerations considers only minor factors in those costs.

2. *Constancy of TCE factors*: Transactions costs are pretty much constant for all major acquisition programs.

    a. If (as asserted above) the government has more scope for opportunistic behavior, then prospective business partners will take that factor into account when considering whether to compete for government business—and build compensation for those risks into their bids. Furthermore, such risk premiums may be fairly constant across various types of projects, such as major acquisition programs.

    b. Every program includes an allowance for managing the contractual relationship (even though it's difficult to assign program management overhead completely to individual programs.) Possibly every program has enough of a management allowance to manage the program reasonably well. Put another way, the rule-of-thumb standard for program management permits individual program managers to deal with transactions difficulties well into the range of diminishing returns. Thus, even though transactions costs vary among programs, the standard program management allocation is sufficient to obscure those differences.

    c. Continuing with this line of reasoning, a variant of Parkinson's Law might apply. That is, for some programs the standard budget for program management is too much. However, program managers—perceiving (probably accurately)—that more program management activity has some marginal return, are strongly inclined to spend all their management budgets.

3. *Transactions Cost factors are already accounted for* in current cost-estimation methods. Measures of risk and complexity (such as technical-readiness indicators) indeed indicate the risk and complexity of the project. Also, however, the presence of those factors also offers increased scope for opportunistic behavior, and with it an increase in transactions cost. That is, the transactions cost elements in major program costs are highly correlated with variables already considered in standard cost-estimating methods.

4. *It all evens out.* Scope for opportunistic behavior cuts both ways. Scope for government opportunism increases (decreases) contractors' (government) costs while contractor

opportunism increases (decreases) government (contractors') costs. On average, it might well balance out.

5. While the effects of TCE considerations are important and a very significant factor in program costs, they're very *hard to find* (and quantify). By definition, opportunistic behavior involves guile (Williamson, 1996), and those who behave opportunistically have already taken pains to conceal their behavior (or assign other motives to it).

Therefore, while there is a persuasive case of the importance of TCE considerations in defense acquisition processes, it's not clear that one would be immediately led to conclude that incorporating TCE principles into cost-estimating models either (a) improves their explanatory power or (b) ameliorates the low-ball biases we observe in current practice. It comes down to a matter of resolving competing hypotheses with empirical data.

C. Testing Our Hypotheses

As shown in the sections above, our research has uncovered reasons to believe that TCE factors are important in DoD acquisition costs, but also that TCE insights may, in fact, not improve cost-estimation methodology. What's left is to sort out the competing claims using the available empirical evidence.

Our hypothesized set of relationships is depicted in Figure 3 below. To reject our null hypothesis, we need to do empirical tests, and have accordingly sought data on major DoD acquisition programs. For *Indicators of High Transactions Costs,* we apply the Powell (2002) stoplight scheme, with special emphasis on asset specificity. For *observable manifestations* of cost problems and governance issues *during the program*, we can consult histories of actual programs. In this report, we use case studies of actual Army acquisition programs compiled by one of our team members (John Dillard). These are reported in Section VII.

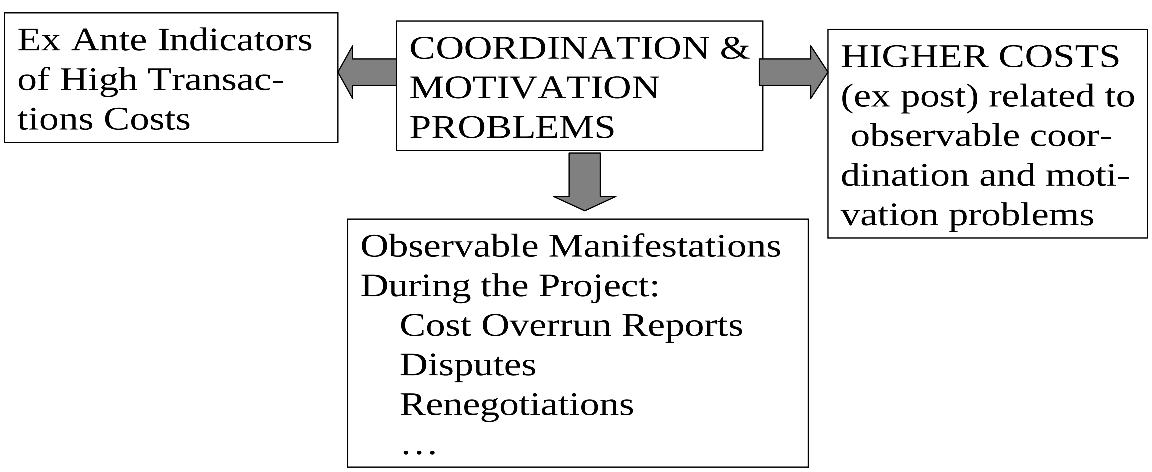

Figure 3. TCE Issues in Acquisition Projects and Hypothesized Cost Manifestations

We've also tracked Program Management Office costs as an indicator of actual transactions costs present within any given program. These are reported in Section VIII.

VII. TCE Applied to Two Defense Acquisition Case Studies

In the some of these authors' previous work (Dillard, Franck and Melese, 2006), fundamentals of transaction cost economics (TCE) were explained and insights from it were applied to defense acquisition. TCE asserts that "make-or-buy" decisions for the needs of a firm ultimately define its own vertical boundaries. And though much of the body of knowledge thus far consists of studies from the private sector, many public concerns engage in outsourcing as well. Defense acquisition is one such very large public enterprise and extends from R&D and procurement of materiel to purchasing services and sustaining support for its military forces. It is unique because, for the most part, the Department of Defense outsources much of what we consider to be "acquisition," commissioning external suppliers to develop products for its internal use, unlike many private and public organizations that conduct internal product development for themselves and others (or external products/services for others). TCE acknowledges that outsourcing relationships can vary widely in their transactional characteristics and can involve extra transaction costs such as measurement, monitoring, and negotiation costs that could negate the initially perceived advantages of the buy-versus-make decision.

TCE is descriptive of economic behavior and recognizes the issue of *motivation*. It assumes that economic actors, such as government acquiring "principals" and defense industry supplying "agents," are motivated to forecast potential outcomes and factor these into contracts. The DoD's general motivation (among, no doubt, other agendas) in its acquisition transactions is the seeking of better products, delivered quickly, and with fewest resources (i.e., performance, schedule, and cost). But such outsourcing is complicated by other phenomena. TCE characteristics of *complexity* (such as technology) and *uncertainty* (such as duration of work) apply clearly to many Defense acquisition transactions and lead to "incomplete contracting," termed as such from imperfect information and our inability to predict the future. These endanger a firm's ability to protect its own interest throughout the transaction, but hopefully are mitigated via governance mechanisms that positively influence a supplier's motivation to comply with the terms of an incomplete contract. These might be via contract incentives, enforcement mechanisms, monitoring methods, etc.

Another often encountered but heretofore largely unrecognized TCE characteristic (at least in Defense acquisition literature) is that of *asset specificity*—a situation in which a supplier "locks-in" the government by making investments in productive assets that are specific to the transaction and have little value elsewhere. Asset specificity can be related to physical capital equipment, human skills, facility location, and even brand equity (reputation). While needed to accomplish the work at hand, the result of these investments form barriers to competitive entry and can also result in a "holdup." A holdup is a problem that occurs when, for example, the agent in a contract has a specific asset with concerns that, after its investment, may have to accept worse terms than anticipated. Conversely, the principal has become increasingly dependent on the agent during his investment in the specific assets. It has become fairly typical in the DoD acquisition experience: with development contracts that are necessarily incomplete, sometimes won by low bids, and changes in contract scope later arise. The contractor can anticipate higher returns from "holding up" the government for such contract modifications. And while the government might have the sovereign right to terminate the contract for convenience, it will still be left with the demand for the product or service that was sought. Such has been the case in several programs observed by these authors, along with excursions into contract type and structure as options for obtaining desired outcomes.

Acquisition Case Examples

One of the authors was fortunate to have served as the Assistant Project Manager for Research & Development in two separate major defense acquisition programs that were offspring of Defense Advanced Research Projects Agency (DARPA) initiatives. These programs are described below to illustrate TCE challenges and uses of governance mechanisms.

The Javelin Project

The Advanced Anti-Armor Weapon System—Medium (AAWS-M), later to become the Javelin, began in 1982 as the DARPA program "Tank Breaker."[14] This was a one-year technology demonstration to explore various missile-guidance solutions for a medium range (i.e., 1-2000 meters) man-portable, anti-tank weapon. It was spawned as a result of deficiencies that were immediately apparent in the recently fielded DRAGON weapon system, which had replaced the M67 90mm recoilless rifle in the late 1970s. The DRAGON was a wire-guided, line-of-sight missile that was developed in response to the 1960s appearance of the Soviet AT-3 SAGGER, a manpack missile carried in a fiberglass "suitcase." In 1978, a Mission Need Statement highlighted deficiencies of the DRAGON, such as its poor reliability, limited range/lethality, and the difficulty for gunners to aim and track targets. The envisioned replacement was to satisfy a substantial increase in requirements—namely: range, lethality, reduced weight, and the ability to launch from enclosures (such as buildings or field-fortified bunkers). Several years were spent finalizing these requirements until the joint Army and Marine Corps operational requirements document was formally approved in 1986-88. A competitive fly-off program, which would now be called the "Technology Development phase," was conducted in 1987-1989 to select from three teams of contractors and critical technologies: a laser-beam rider led by Ford Aerospace, a fiber-optic guidance effort led by Hughes, and a forward-looking infrared (FLIR) thermal imaging sensor effort from Texas Instruments and Martin-Marietta. Clearly, the down-selection to one team was of great incentive to the participants, for it meant the likely follow-on award of the advanced development phase as well as production opportunities. Cost Plus Fixed Fee (CPFF) contracts were used with each of the three teams. Such is typical for "proof-of-principle" type R&D efforts in which knowledge work is risky for the contractor, and there are few discrete parameters to incentivize. All three teams were successful in flying missiles to their targets, but the only technology that enabled a true fire-and-forget capability (which was not a specified requirement) was the FLIR approach. Though this approach was recognized to be the most technically immature and risky, the desire for fire-and-forget survivability resulted in the FLIR team being awarded a contract for a three-year advanced-development phase.

In June of 1989, a full-scale development (now called System Development and Demonstration) contract was awarded for the Javelin program. The program was structured to encourage competition and give incentives for the accomplishment of all of the system objectives of the Department of Defense. First of all, the contract would be awarded to a team of two partnering firms that would combine their efforts for development of the system and split apart to compete during the production phase. The initial low-rate production was envisioned to be a competitive split awarded annually with a fifty/fifty or sixty/forty split between partners, via the use of fixed-price contracts. Such contracts are also typical for production efforts in which the design (uncertainty and complexity) is presumed to have evolved to a point of stability. At

---

[14] DTIC reports summarizing this DARPA effort are available at http://stinet.dtic.mil/oai/oai?&verb=getRecord&metadataPrefix=html&identifier=ADA122234.

the macro level, the office of the Secretary of Defense viewed the program as acceptable with regard to risk because of its 27-month technology development phase and subsequent 36-month plan for full-scale development.

During the technology-development phase, all three contractor teams had scored over 62% hits with at least ten missile shots each in a variety of environments and operational settings. The full-scale development contract request for proposal was written for a cost-plus-incentive-fee type of contract, but the winning proposal was presented with a “no-fee” bid. This surprised the Government, which nevertheless awarded a cost-plus-incentive-fee contract, giving incentives for key performance parameters such as weight and warhead performance that it considered technically risky. The total value of the contract was $169.7 million, the amount bid by the winning team of Texas Instruments and Martin-Marietta. Meanwhile, the Government privately conducted its own should-cost estimate and budgeted $263 million for the 36-month long development effort. In addition, the Government ran its own alternate warhead technology development program with CMS acting as the contractor.

The two-partner Joint Venture in full-scale development was also free to maximize competition at the subcontractor level. In their make-versus-buy decision, Texas Instruments elected to make the focal plane array for both of its uses in the command launch unit and in the missile. They had made these devises for other programs but not in these two distinct configurations. Their physical-specific assets were located at the manufacturing facility in Lewisville, Texas, largely for the promise of the Javelin system’s later production. They had expanded that facility for the Javelin program in anticipation of producing some 58,000 to 70,000 missiles and 5,000 command launch units (the thermal imaging sighting device).

Each missile focal plane array was forecasted to be approximately 15% of the missile's cost (or about $12,000 for each of the focal plane arrays) based upon a $90,000 “cost per kill” program objective. Focal plane array technology was still immature and would be gauged today at approximately technology readiness level five (on a 1-9 scale), despite its successful technology development phase results. It was always recognized as technologically risky, so the Government partially funded other companies that could produce these devices. In 1991, the only five known FPA makers in the world were Rockwell International, Loral, Santa Barbara Research Corporation, Sofradir (a French firm), and Texas Instruments.

As an additional gauge of technological maturity, a baseline test was mandated at the second milestone upon the decision to launch the Javelin program into full-scale development. That test would pit the immature focal plane array technology against existing TOW and DRAGON (legacy systems) missile optics. Results of this test showed the Javelin's immature focal plane arrays to be substantially better in performance than the DRAGON and almost as good or as good as the larger TOW anti-tank missile system.

Approximately 18 months after the full-scale development phase contract award, the Javelin project manager called for Defense Acquisition Board, forecasting a Nunn-McCurdy breach of cost and scheduling thresholds in this ACAT 1-D program. Several reasons were cited, not the least of which was that the focal plane array production yield was not as predicted—and all of the devices were below specification. The cost growth was found throughout the various elements of the project, as illustrated in Table 2 below.

Over the next year, the program was given a new baseline with many different revised program estimates climbing from 36 months duration and $298 million in cost, to 48 months duration and $372 million in cost, and then to 54 months and $420 million for the total cost and duration of this phase. In addition to the rebaselining, the Government renegotiated its cost-plus-incentive-fee contract with the joint venture and established cost sharing for any expenditure above $372 million, all the way to the contract ceiling of $420 million.

This was a very unique move, to re-establish governance mechanisms in the middle of a transaction. But the contractor's "failure to perform," although in an uncertain R&D environment, justified the new relationship. At 30 months after contract award, the program was finally formally re-baselined to be 54 months and $443 million, with 50/50 JV and Government cost-sharing ratio above that amount.

In October of 1991 at a meeting in the Lewisville, Texas, focal plane array manufacturing facility, the "divorce" finally came for TI as prime vendor of the missile focal plane array. Texas Instruments had failed to achieve specification for the item by the target date, but they still had a stake in the program as one of the principal players on the joint venture team.

About this same time, the Government discovered a focal plane array "holding account" that had been proposed and was awarded in scope of the contract. Essentially, this holding account accrued charges to the Government for every non-specification compliant focal plane array that TI had produced. The cumulative total was to be billed all at once, when they achieved the first specification-compliant focal plane array.

ADVANCED ANTITANK WEAPON SYSTEM - MEDIUM (AAWS-M)

AAWS-M
CONTRACT COST GROWTH
(JUN 89 TO PRESENT)

	ORIGINAL BUDGET	CURRENT LRE	DELTA
1. ROUND & MISSILE	11,733	20,048	(8,315)
2. PROPULSION	2,327	8,386	(6,059)
3. WARHEAD/CONTACT FUZE	9,720	13,661	(3,941)
4. ELECTRONIC SAFE AND FIRE	1,459	6,926	(5,467)
5. GUIDANCE SECTION	16,092	35,662	(19,570)
6. SEEKER	24,227	47,905	(23,678)
INCLUDES FOCAL PLANE ARRAY	[14,000]	[33,000]	[19,000]
7. CONTROL ACTUATION SYSTEM	2,046	5,180	(3,134)
8. TELEMETRY	2,405	4,085	(1,680)
9. LAUNCH TUBE ASSEMBLY	2,036	6,583	(4,547)
10. BATTERY COOLANT UNIT	1,155	4,849	(3,694)
11. ROUND SHIPPING CONTAINER	107	2,420	(2,313)
12. COMMAND LAUNCH UNIT	18,976	53,812	(34,836)
INCLUDES DETECTOR DEWAR COOLER	[2,600]	[15,100]	[12,500]
13. TRAINING DEVICES	7,755	9,636	(1,881)
14. TEST & EVALUATION	11,260	12,510	(1,250)
15. SYSTEM ENGINEERING	9,362	21,606	(12,244)
16. PROJECT MANAGEMENT	35,298	64,596	(29,298)
17. INTEGRATED LOGISTICS SUPPORT	3,949	6,070	(2,121)
18. DATA	4,026	4,505	(479)
19. JOINT VENTURE G&A	11,591	20,247	(8,656)
ALL OTHER	4,559	13,465	(8,906)
TOTAL	180,083*	362,152	(182,069)

*$169.7M + CONTRACT MODS

Table 2. Early 1991 Summary of Javelin Program Component Cost Growth

Since the contract was cost-reimbursable in form, the Government was likely to have to pay for all costs of development regardless of spec compliance, but the way the billing transpired took the Government by surprise. Fortunately, dual sourcing of critical components is a fundamental element in acquisition strategy development and risk mitigation. And the selection of Hughes's Santa Barbara Research Corporation as a sub-contractor to the other Joint Venture partner, Martin-Marietta, saved the Javelin program. That small company had discovered a process to produce near-perfect focal plane arrays repeatably, and they were accelerated to provide these for the program. The investment was, in hindsight, a "real option" that was exercised mid-project with great return on investment.

Within that year, the program was restructured, given the new baseline, and finished largely within its new parameters. The additional 18 months added to the 36-month phase helped resolve the uncertainties and complexities of system development without additional schedule slippage. Later, production quantities were slashed in half as the Defense Department drew down its forces from 1991-2000, and the acquisition strategy to split apart the joint venture and compete them in production was not fulfilled. Benefits of a split production no longer able to be realized, the JV remained intact as the producing entity. Today Javelin is seen as a successful weapon system, is being used in Iraq and Afghanistan and has been through several full-rate production contract periods.

The Army Tactical Missile System Project

The Army Tactical Missile System also started out as a DARPA program, called Assault Breaker, in the 1970s. The system's prime contractor for the vehicle, the Multiple Launch Rocket System, or MLRS, was LTV Corporation. With significant asset specificity from their platform efforts (and physical & knowledge capital), they bid upon and won two separate contracts for the Army Tactical Missile System. These were both firm-fixed-price: one for the invention of the missile and one for its integration into the platform. The program was a 48-month full-scale development effort that was begun in 1986 and ended in 1990. In stark contrast to the Javelin program, fixed-price contracts were deemed appropriate to this transaction because of the technology maturity in the ATACMS project, relative to most others, where CPIF contracts are common—as depicted in Table 3.

Key Program Characteristics - First Increment of Capability

Program Aspects	ATACMS	JAVELIN
DARPA Predecessor	Assault Breaker 1977-82	Tank Breaker 1981-82
Ultimate Capability	*"Deep Attack"*	*"Fire & Forget"*
Critical Technologies & Readiness Levels:		
Munition	9 - Lance M74 Bomblet	5 - Tandem Shaped Charges
Propulsion	9 - Solid Rocket Motor	5 - Two-Stage Solid Rocket Motor
Flight Control	9 - Fin surfaces	6 - Fins + Thrust Vector Control Vanes
Guidance and Control	9 - Inertial	4 - Tracker Software Algorithm
Safe/Arm Fusing	7 - Mechanical	4 - Electronic
Software Function (Target Acquisition, Fire Control, etc.)	6 - Various	6 - Various
Sensor	N/A	5 – Focal Plane Array
Capability Leap Area	Range	Range, Lethality, Survivability
Cost of development	~$700M	~$700M
Contract Type	Fixed Price	Cost Reimbursable
Tech Development Phase	0 Months	27 Months
Advanced Development Phase - Planned	48 Months	36 Months
Advanced Development Phase - Actual	51 Months	54 Months
Total Time in Development	51 Months	81 Months
Advanced Development Phase Contract Cost Growth	0%	>150%

Table 3. Comparison of Programs Using Different Contract Types and Technology Readiness Levels

Also, this program was structured to have production options, should the full-scale development phase be successful. Thus, there were incentives for "performance" on both the Government and the contractor side: LTV was given an incentive to succeed in the development of the missile and its integration in order to win the follow-on low- and full-rate production contracts. And likewise, the Government had an "incentive" to conduct reviews and make decisions to award production by November of 1990. This was to preserve production-pricing options that the contractor had been asked to provide in his proposal for advanced development. The price reduction from these options, if exercised before expiration, was on the order of 40%. As it turned out, the production options were exercised within a week of their expiration, saving the Government several hundred thousand dollars per missile on the eve of the first Persian Gulf War.

These cases may only serve to illustrate several recognized economic behaviors within the context of large acquisition transactions. As an adjunct to our earlier work (Dillard, Franck & Melese, 2006), they show how complexity and uncertainty of development projects relate to contract type and governance mechanisms. Importantly, they also convey the need to constrain scope in order to control cost and schedule. In and of themselves, they cannot necessarily prove cause and effect, but rather reveal the importance of understanding key characteristics of a transaction early in the cost-estimation process in order to capture relevant transaction cost elements that can impact the ultimate price paid for major weapon systems.

TCE Assessment of the Case Studies

As indicated in Section VI above, we looked for observable effects of TCE factors in actual DoD acquisition programs. This section analyzes the two cases (Javelin and ATACMS) described above in terms of: (1) ex ante indicators of transactions costs, (2) manifestations of motivation and coordination problems in the course of the program, and (3) cost overruns observable at program completion.

The ex ante indicators come from a scheme proposed by Powell (2002) and augmented by Franck (2004). The indicators of transaction costs considered here are asset specificity, complexity, length of the relationship (or transaction), time sensitivity of performance, and operational significance of performance.

TCE Indicator	Assessment	Comments
Asset Specificity	YELLOW	TI's insourcing of FPA production. Mitigated by planned dual-source production, and steps to diversify FPA sources.
Complexity	RED	Fire-and-forget feature added significantly to complexity.
Length of Relationship	YELLOW	Technical immaturity necessitated a lengthy development program.
Time Sensitivity	YELLOW	Green after end of Cold War.
Operational Significance	YELLOW	Green after end of Cold War

Table 4. Ex Ante Assessment of Javelin Development Program

TCE Indicator	Assessment	Comments
Asset Specificity	RED	Pre-existing condition. Contractor's previous experience with launch vehicle. Production option proved a hedge for the contractor.
Complexity	GREEN	Technology generally mature
Length of Relationship	GREEN	Advanced Development Phase only.
Time Sensitivity	YELLOW	Green after end of Cold War
Operational Significance	YELLOW	Green after end of Cold War

Table 5. Ex Ante Assessment of ATACMS Development Program
(Powell (2002), Franck (2004) and authors' assessments)

The relative immaturity of Javelin technologies necessitated a long and complex transaction. Worth noting is that a government decision, in favor of the fire-and-forget feature, increased these difficulties.[15] By contrast, the ATACMS development program was based largely on proven technologies. For both development programs, Time Sensitivity and Operational Significance decreased considerably with the end of the Cold War. Both ATACMS and Javelin were designed to counter massive Warsaw Pact mechanized offensives, at the

[15] We have no basis to question (from an ex ante perspective) the Army's decision to opt for a less mature technology in pursuit of significantly higher performance. However, we believe consideration of the increase in scope for opportunistic behavior in the program should be considered when making such decisions.

operational and tactical levels respectively. With the end of the Cold War, both priority (operational significance) and urgency (time sensitivity) lessened accordingly. Arguably, this development significantly strengthened the government's position in the negotiations associated with governance of both programs.

Observable manifestations of motivation and coordination difficulties during the course of the project are gleaned from the narratives above. For Javelin, there were a number of difficulties apparent throughout the problem, predictable from a TCE perspective. These included the following.

- The winning bid clearly seems to have been a buy-in. The contracting team's initial estimate was significantly below the government's estimate of most likely program cost. From a TCE perspective, this can be interpreted as setting the stage for opportunistic behavior on behalf of the contractors.
- One member (Texas Instruments) of the development team (the Joint Venture) chose to make the Focal Plane Arrays (FPAs) within firm boundaries. The FPAs were arguably the critical, and pacing, element of the Javelin development program. Whether this indicates opportunistic behavior by TI, or simply a miscalculation, is difficult to assess. Worth noting, however, is that the Army took steps toward developing an alternate source. A TCE perspective would indicate the government perceived some scope for opportunistic behavior; a risk-management perspective would interpret this as a risk reduction measure.
- There was steady, and cumulatively very significant, cost growth throughout the program. As a result, the Program Manager reported breaches of criteria for both cost and schedule—relatively early during the program.
- Other cost-growth problems appeared. For example, the bill for FPA's not meeting specifications was presented to the government without previous notice. This turned out to be an unpleasant surprise. Whether this was simply a communications difficulty or opportunistic behavior on the part of the Joint Venture is not clear.
- Consequently, governance of the transaction became significantly more complicated. Major changes to program structure were negotiated as part of a "re-baselining." Additionally, the contract's incentive structure was changed— from a cost-plus to a risk-sharing form.

Overall, there was significant cost growth (over 150%) in the Javelin development program.

For ATACMS, the only major indicator of transactions cost-related difficulties was asset specificity. LTV's previous experience with the launch vehicle (the MLRS) gave it a substantial advantage over alternate vendors—making this an excellent example of what can happen with asset specificity. However, the program was executed on schedule and within the original cost estimate. It's possible that LTV had no incentive to low-ball its original estimate with its already significant advantages over potential competitors based on asset specificity.

There was arguably evidence of opportunistic behavior on the part of the government.

- A program based on a fixed-price contract was extended by three months (from 48 to 51) simply because of governmental convenience—without compensation to the contractor.

- Also, the government was slow to exercise its option to order the start of production, and would likely have delayed its decision further were it not for the imminent expiration of a favorable price option in the contract. It's reasonable to suppose that this part of the contract served to head off opportunistic behavior on the part of the government.

Some observations are useful at this point. First, the indicators of high transactions costs should be considered *in toto*. As we've stated above, there are excellent reasons to believe that asset specificity is particularly important in creating conditions for opportunistic behavior in a transaction. However, in the case of ATACMS, there appears to have been no bad behavior that added significantly to program outcomes (cost, schedule or performance), despite the RED assessment for asset specificity.

Second, opportunistic behavior in transactions is a question of motives, and it's difficult to sort out motives in case narratives. For example, was the contractors' original estimate for Javelin development a buy-in or a manifestation of the Winner's Curse? Was the unexpected presentation of the bill for substandard Javelin FPAs a matter of opportunistic behavior (self-interest seeking with guile) or simply an administrative failure to communicate? Without considerably more information that's available in the public record, it's difficult to sort out such matters.[16]

However, finally, there is good evidence that TCE perspectives offer significant explanatory power in analyzing program outcomes—including cost. Based on this sample of two, however, it's explanation of the qualitative sort. Our next section (VIII) explores quantitative evidence of transactions costs at a macro level.

VIII. Program Office Costs and TCE

In order to test our hypothesis that the traditional WBS approach may overlook some important variables resulting in unrealistically low initial cost estimates, we would have to compare cost estimates for systems that included significant transaction costs with those of systems that did not include significant transaction costs. The first problem, then, was to find a way to measure transaction costs in acquisition programs. We proposed using Program Management Office (PMO) costs as a proxy measure of the amount of transaction costs present in an acquisition program.

We started by examining information from the Consolidated Acquisition Reporting System (CARS) to find evidence of transaction costs. The information is contained in the Defense Acquisition University (DAU) Business Information Laboratory (BIL) database managed by OUSD(AT&L) Acquisition Resources and Analysis. It includes information on contract performance and program cost from a variety of reports, such as Selected Acquisition Reports (SAR) and Defense Acquisition Executive Summaries (DAES), as well as other reports. Unfortunately, these reports do not contain the level of detail necessary to identify transaction costs. Specifically, there was no information on the amount of resources estimated or used for the PMO.

Instead, we looked at the Budget Item Justification sheets in the OSD budget (http://www.defenselink.mil/comptroller/budgetindex.html). While there is some information on PMO costs in these documents, it is reported inconsistently or not at all (depending on the

[16] The obvious incentives to conceal the motives underlying self-seeking behavior add to this difficulty.

program and year). For example, the Marine Corps Advanced Amphibious Assault Vehicle (AAAV)[17] reported Program Office costs in exhibit R-3 under “Support and Management Organizations” for FY97 and FY98, but discontinued reporting that line-item in subsequent years. Note also that what is included in PMO costs is not a complete picture of the resources used, since military salaries are excluded and civilian salaries may or may not be included depending on how they are funded.

The AAAV reported costs for the more general category “Support and Management” for FY97 – FY06, but the line-items included in this category varied from year to year. If we expand our proxy measure to the “Support and Management” category, we are including, in addition to Program Office costs, other support contracts, miscellaneous contracts and government labs, as well as modeling and simulation. As the program developed, this category grew to include integrated logistics support, training devices and simulators, tech data and publications development and support equipment development. Clearly, this category includes costs that should not be considered transaction costs, such as training devices and simulators and tech data and publications. More importantly, what is and is not included in the category varies over time, making the identification of transaction costs difficult on a case-by-case basis and nearly impossible on a large scale.

A more significant problem we encountered is that the information reported in CARS does not necessarily track to the information reported for the same program in the OSD budget. This problem was confirmed by OUSD(AT&L) Acquisition Resources and Analysis and is an issue they have been working on for over 3 years and have documented in a *Comparison Report* that identifies potential FY07 funding disconnects between the OUSD(Comptroller) Budget Justification Materials and the OUSD(AT&L) Draft Selected Acquisition Reports.

Contributing to the difficulty of identifying program transaction costs is the fact that program managers only report information on a program's major contracts for RDT&E, procurement, military construction, and acquisition-related operation and maintenance. According to the CARS *Users' Guide*, SAR Section 15 (Contract Information) only includes the six largest, currently active contracts (excludes subcontracts) that exceed $40 million in then-year dollars. For a given reporting quarter, these are generally the same contracts reporting in Section 6 (Program Background Data) of the DAES. If a previously reported contract is over 90% complete, it will no longer be reported. So, tracking Budget at Completion (BAC) and Estimate at Completion (EAC) at the program level involves moving targets as the individual contracts are completed and drop out of the CARS. Also, the total amount shown for the program in the OSD budget may include other contracts not reported in CARS.

Due to the data difficulties described above, we were unable to test our first hypothesis using our selected proxy measure for transaction costs. In fact, it seems measuring transaction costs directly or by proxy from the existing data bases may not be possible.

As an alternative, we could always infer that differences due to complexity or technology maturity imply higher transaction costs and use this categorization to compare programs with assumed high transaction costs to programs with assumed low transaction costs. For example, Brown, Flowe and Hamel define transaction costs as costs associated with interdependent activities, and they suggest that joint programs (involving two or more services) would have higher transaction costs than single-service programs. Certainly, the coordination costs could

[17] The name of this program changed to Expeditionary Fighting Vehicle (EFV) in FY03.

be assumed to be higher for joint programs. When they examined 84 DoD weapon system programs (45 joint and 39 single) in terms of number and type of programmatic breaches, they found that joint programs were statistically more likely to experience breaches in schedule, research development testing and evaluation costs and unit costs. If we assume joint programs have higher transactions costs, then their findings may suggest that programs with higher transactions costs require distinct measures and metrics to improve cost and schedule estimates.

IX. Summary and Policy Recommendations

Developing accurate cost forecasts is essential for future budgeting and to improving defense decision-making. This paper has documented a growing body of evidence of a systematic downward bias in initial cost estimates for major weapon systems. An important consequence of these forecasting difficulties is that "major weapon systems […] are experiencing recurring problems with cost overruns, missed deadlines, and performance shortfalls" (GAO, 2006, March, p.1). Runaway costs threaten to weaken the armed forces. Cash-flow shortfalls lead to quantity reductions, reprogramming, and funding reductions for other programs. These cost increases mean that the DoD cannot produce as many weapons as intended nor deliver those weapons to the warfighter when promised. Cost overruns squeeze existing and competing programs. Higher price tags mean that fewer of those weapons end up in the hands of soldiers, and that options on new weapons cannot be exercised without breaking the budget.

Two factors are usually blamed for unrealistically low cost forecasts: bad incentives (psychological and political-economic explanations) and bad estimates (methodological explanations). The focus of this paper is on cost methodology. The case studies suggest that inclusion of transaction costs as a recognized component of total cost adds to explanatory and forecasting power of cost-estimation methods. However, we also found that current data bases are not well structured for identifying the transaction costs of major acquisition programs—for a number of reasons.

What can be done to reduce actual costs/expenditures? TCE suggests identifying strategies to cut coordination and motivation costs. Specific recommendations to cut Coordination and Motivation Costs would include the following:

a. Reducing Complexity: Investing in a more complete contract (increasing search and information costs) and the use of more mature technologies.
b. Reducing Uncertainty through multi-year contracts (demand uncertainty); investing in more complete contracts (relationship uncertainty).
c. Increasing measurement and monitoring to reduce information asymmetries (and associated risks).
d. Putting credible deterrents to bad behavior in place—such as penalty clauses, warranties and bonding; using multi-year contracts to gather information and reward good reputations.
e. Mitigating the uncertainties introduced by asset specificity through careful use of incentives, proper bundling of goods and services and GOCO assets.

f. Increasing contestability of government contracts through government-controlled standby capacity (threat of vertical integration), second sourcing, and preservation of real options (threat of entry of competing suppliers).

That said, however, the primary insight drawn from TCE is that correctly estimating production costs is necessary, but not sufficient. The choice of contract, organization, and incentives—along with key characteristics of markets and transactions (uncertainty, complexity, asset specificity, frequency, and contestability)—must be included to obtain reliable cost estimates. Leveraging TCE in this way could help characterize, explain, forecast, and ultimately reduce the cost growth that plagues many of today's major investments in military capabilities.

REFERENCES

Alchian A., & Demsetz, H. (1972). Production, information costs and economic organization. *American Economic Review,* 62, 777-795.

Arena, Mark V. et. al. (2006). *Historical cost growth of completed weapon systems.* Santa Monica, CA: RAND.

Ashley, D., & Workman, R. (1986). *Incentives in Construction.* Austin, TX: Construction Industry Institute.

Bajari, P., & Tadelis, S. (1999). *Incentives versus transaction costs: A theory of procurement contracts*. Dept. of Economics Working Paper. San Francisco: Stanford University.

Besanko, D., et. al. (2000). *Economics of strategy* (2d ed.). New York: Wiley.

Bhagwati, J. (1980). Lobbying and welfare. *Journal of Public Economics*, 14, 355-63

Blanchard, B.S., & Fabrycky, W.J. (2006). *Systems engineering and analysis* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Brown, M.M., Flowe, R.M., & Hamel, S. (2006). The acquisition of joint programs: The implications of interdependence. working paper.

Coase, R. (1937). The nature of the firm. *Economica,* 4, 386-405.

Dillard, J., Franck, R., & Melese, F. (2006, September 30). *A transactions cost economics approach to defense acquisition management*. Monterey, CA: Naval Postgraduate School.

Franck, R. (2004). *Business case analysis and contractor vs. organic support* (NPS-AM-04-013). Monterey, CA: Naval Postgraduate School.

Franck, R., & Melese, F. (2005). A transaction cost economics view of DoD outsourcing. In *Proceedings* of NPS Second Annual Acquisition Research Symposium. Monterey, CA: Naval Postgraduate School.

DoD. *Consolidated acquisition reporting system (CARS) user's guide*. Update retrieved April 2007, from http://www.acq.osd.mil/cars/Downloads/CARS%20Users%20Guide.doc

DoD. (2003, May 12). *DODI 5000.2*, enclosure 2. Retrieved April 2007, from http://asks.dau.mil http://akss.dau.mil/DAG/DoD5002/Enclosures_2.asp

DoD. (2005). Work breakdown structures for defense materiel items*. Military Handbook 881A*. Washington, DC: Department of Defense.

GAO. (1997). *Department of Energy: Opportunities to improve management of major system acquisitions* (GAO RCED 97-17)*.* Washington, DC: General Accountability Office.

GAO. (2006, March). *Defense acquisitions: Assessment of selected major weapons programs* (GAO-06-391). Washington, DC: General Accountability Office.

GAO. (2006, April). *Defense acquisitions: Actions needed to get better results on weapons systems investments* (GAO-06-585T). Washington, DC: General Accountability Office.

GAO. (2007). *Defense acquisitions: Assessment of selected weapon programs* (GAO-07-406SP). Washington, DC: General Accountability Office.

Makison, L. (2004, September 29). *Outsourcing the Pentagon*. Washington, DC: The Center for Public Integrity. Retrieved from www.publicintegrity.org.

McNicol, D.L. (2005). *Cost growth in major weapon procurement programs* (2nd ed). Washington, DC: IDA.

Pigeon, N., et. al. (2006). *The use of alternative dispute resolution techniques in United States Air Force environmental conflicts.* In *Proceedings* of the NPS Third Annual Acquisition Research Symposium. Monterey, CA:.Naval Postgraduate School.

Pint, E., & Baldwin, L. (1997). *Strategic sourcing: Theory and evidence from economic and business management* (MR-865-AF). Santa Monica, CA: RAND.

Powell, C.A. (2002). *Transactions cost economics and A-76: A framework for defense managers* (thesis). Monterey, CA: Naval Postgraduate School.

Tullock, G. (1971). The cost of transfers. *Kyklos*, 24, 629-43

Tullock, G. (1993) *Rent seeking*. Cambridge: Elger, University Press.

Williamson, O. (1971, May) The vertical integration of production: Market failure considerations. *AER*, 61, 112-123.

Williamson, O. (1979) Transaction-cost economics: The governance of contractual relations. *Journal of Law and Economics,* 22, 233-261.

Williamson, O. (1985) *The economic institutions of capitalism*. Free Press: New York.

Williamson, O. E. (1996). *Mechanisms of governance*. New York: Oxford UP.

Williamson, O. (1999). Public and private bureaucracies: A transaction cost economics perspective. *Journal of Law Economics and Organization*, 15, 306-42.

Williamson O. & Masten, S. (1999). *The economics of transaction costs*. Northampton, MA: Elger.

Wintrobe, R. (1997). Modern bureaucratic theory. In D. Mueller (ed.), *Perspectives in public choice: A handbook*. Cambridge: Cambridge University Press.

Wolff, J. & Reed, R. (2000). Firm resources and joint ventures: What determines zero-sum vs. positive-sum outcomes? *Managerial and Decision Economics,*21, 269-284.

THIS PAGE INENTIONALLY LEFT BLANK

2003 - 2006 Sponsored Acquisition Research Topics

Acquisition Management

- Software Requirements for OA
- Managing Services Supply Chain
- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Portfolio Optimization via KVA + RO
- MOSA Contracting Implications
- Strategy for Defense Acquisition Research
- Spiral Development
- BCA: Contractor vs. Organic Growth

Contract Management

- USAF IT Commodity Council
- Contractors in 21st Century Combat Zone
- Joint Contingency Contracting
- Navy Contract Writing Guide
- Commodity Sourcing Strategies
- Past Performance in Source Selection
- USMC Contingency Contracting
- Transforming DoD Contract Closeout
- Model for Optimizing Contingency Contracting Planning and Execution

Financial Management

- PPPs and Government Financing
- Energy Saving Contracts/DoD Mobile Assets
- Capital Budgeting for DoD
- Financing DoD Budget via PPPs
- ROI of Information Warfare Systems
- Acquisitions via leasing: MPS case
- Special Termination Liability in MDAPs

Logistics Management

- R-TOC Aegis Microwave Power Tubes
- Privatization-NOSL/NAWCI
- Army LOG MOD

- PBL (4)
- Contractors Supporting Military Operations
- RFID (4)
- Strategic Sourcing
- ASDS Product Support Analysis
- Analysis of LAV Depot Maintenance
- Diffusion/Variability on Vendor Performance Evaluation
- Optimizing CIWS Lifecycle Support (LCS)

Program Management

- Building Collaborative Capacity
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to Aegis and SSDS
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Terminating Your Own Program
- Collaborative IT Tools Leveraging Competence

A complete listing and electronic copies of published research within the Acquisition Research Program are available on our website: www.acquisitionresearch.org

Acquisition research Program
Graduate school of business & public policy
Naval postgraduate school
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CALIFORNIA 93943

www.acquisitionresearch.org