NPS-AM-09-152

ACQUISITION RESEARCH SPONSORED REPORT SERIES

The Economic Evaluation of Alternatives

4 January 2010

by

Francois Melese, Professor

Defense Resources Management Institute (DRMI)

School of International Graduate Studies

Naval Postgraduate School

Prepared for: Naval Postgraduate School, Monterey, California 93943

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

The research presented in this report 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

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL

Abstract

This study offers a comprehensive set of approaches for procurement officials to structure public investment decisions. Designed to improve acquisition outcomes, the "Economic Evaluation of Alternatives" (EEoA) addresses a significant weakness in most contemporary military applications of the current methodology—the Analysis of Alternatives (AoAs). While AoAs correctly focus on lifecycle costs and the operational effectiveness of alternatives, "affordability" is an after-thought—at best only implicitly addressed as a weight placed on cost in the final stages of the analysis. In sharp contrast, the EEoA encourages senior analysts and decision-makers to include affordability explicitly and up-front in structuring an AoA. This requires working with vendors to build alternatives based on a reasonable spectrum of possible funding (budget or affordability) scenarios. A key difference between traditional AoAs and the EEoA approach is that instead of modeling competing vendors as points in cost-effectiveness space, the EEoA solicits vendor proposals as functions of optimistic, pessimistic, and most-likely funding (budget) scenarios. The Decision Map offered in the concluding section of this study provides a comprehensive guide to EEoA for practitioners. This study also illustrates how, by embedding affordability directly into an AoA, the EEoA approach provides a unique opportunity for senior leadership to achieve a significant defense acquisition reform—to integrate Requirements Generation and Defense Acquisition with the Planning, Programming, and Budgeting System (PPBS), reducing future costs and improving performance and schedules.

Keywords: Public Investment, Acquisition Outcome, Economic Evaluation of Alternatives (EEoA), Analysis of Alternatives (AoAs), Defense Acquisition Reform

THIS PAGE INTENTIONALLY LEFT BLANK

Acknowledgments

I am grateful to colleagues at the Defense Resources Management Institute (DRMI) and the Graduate School of Business & Public Policy (GSBPP) at the Naval Postgraduate School, to defense-economics colleagues at the RAND-organized sessions of the Western Economics Association, and to the Honorable Jacques Gansler and other current and former Pentagon officials for ideas and inspiration that led to this study. Given the lively debates that surround this topic, I am solely responsible for the views expressed and for any errors. I also gratefully acknowledge Admiral Jim Greene, Dr. Keith Snider and GSBPP's Acquisition Research Program for funding this study. The usual disclaimers apply.

THIS PAGE INTENTIONALLY LEFT BLANK

About the Author

Dr. Melese joined the Naval Postgraduate School in 1987 and today is Professor of Economics at the Defense Resources Management Institute (DRMI). He teaches executive management courses at the Naval Postgraduate School and in countries around the world. He has been an advisor and consultant to the Joint Staff and the Office of the Secretary of Defense, and in 2008 helped edit the DoD's first *Strategic Management Plan*. He has published extensively on a variety of topics, including a recently co-authored paper entitled "SUCCESS: A New Management Model for Government" implemented in the Joint Staff. At the request of NATO HQ and the State Department, Dr. Melese has represented the US as an expert in defense management and public budgeting throughout Europe. He recently organized a major NATO meeting in Monterey on the occasion of the 60th Anniversary of the alliance: "Building Integrity and Defense Institution Building."

Francois Melese, Ph.D.
Professor of Economics
Defense Resources Management Institute (DRMI)
School of International Graduate Studies
Naval Postgraduate School
Monterey, CA 93943-5000
Tel: 831-229-3179____
E-mail: fmelese@nps.edu

THIS PAGE INTENTIONALLY LEFT BLANK

NPS-AM-09-152

ACQUISITION RESEARCH SPONSORED REPORT SERIES

The Economic Evaluation of Alternatives

4 January 2010

by

Francois Melese, Professor

Defense Resources Management Institute (DRMI)

School of International Graduate Studies

Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

THIS PAGE INTENTIONALLY LEFT BLANK

I. Introduction

A. Making the Case for "Affordability"

> "An AoA is an analytical comparison of the operational effectiveness… and life-cycle cost of alternatives that satisfy established capability needs."
> (DoD, 2006, July 7, Section 3.3)

America's security, billions of taxpayer dollars, and the survival of US soldiers can all hinge on an Analysis of Alternatives (AoA).[1] Routinely conducted to support major military investment decisions, the AoA is a core component of the defense acquisition process. AoAs shape future forces, influence defense spending, and occasionally redefine the defense industry.

This paper reveals a significant weakness in the Multiple-criteria Decision-making (MCDM) approach that underpins many contemporary AoAs.[2] The weakness is that while MCDM techniques, and therefore most AoAs, correctly focus on lifecycle costs and the operational effectiveness of alternatives, "affordability" is an after-thought, often only implicitly addressed through a weight assigned to costs. As Norm Augustine, the former chairman of Lockheed Martin Corp. (and current BENS task force chair on defense acquisition reform), explains: "affordability is rarely considered" (as cited in Newell, 2009).

This paper offers a comprehensive set of approaches for procurement officials to structure public investment decisions to improve acquisition outcomes. Called the Economic Evaluation of Alternatives (EEoA), these approaches address a significant weakness in most contemporary military Analyses of Alternatives (AoAs):

---

[1] This study often uses the term "Analysis of Alternatives" (AoA) in its broad, generic sense. Although focused on defense acquisition, the results of the study apply to any public-sector procurement. It should be clear in context whenever the term AoA references Major Defense Acquisition Programs (MDAPs) or the acquisition of Major Automated Information Systems (MAISs).

[2] For examples of the MCDM approach, see Clemen (1996), French (1986), Keeney (1982; 1992), Keeney & Raiffa (1976), or Kirkwood (1997).

affordability. An important goal of the EEoA is to encourage and guide analysts and decision-makers to integrate affordability early in the acquisition process.

In sharp contrast to traditional AoAs, the Economic Evaluation of Alternatives (EEoA) explicitly addresses affordability up-front. This requires working with vendors to build proposals based on funding (resource/budget) scenarios. The key difference between the MCDM approach to AoAs and the EEoA approach is that instead of modeling decision alternatives from competing vendors as points in cost-effectiveness space, the EEoA generates vendor proposals as functions of optimistic, pessimistic, and most-likely funding (resource/budget) scenarios.

Given the current economic crisis and future public-spending challenges, affordability is a growing concern. As a consequence, it is imperative that the Department of Defense (DoD) obtain the best value for every dollar it invests in its Major Defense Acquisition Programs (MDAPs) and Major Automated Information Systems (MAISs). The primary goal of this study is to improve defense decisions by bringing the taxpayer up-front alongside the warfighter in the defense acquisition process. This is accomplished by explicitly embedding affordability into AoAs. The US Government Accountability Office (GAO) confirms that a major challenge facing the DoD is to "achieve a balanced mix of weapon systems that are affordable" (GAO, 2009, March 18, p. 5).[3]

Unlike the traditional MCDM approach to AoAs that focuses on costs and operational effectiveness (schedule and performance), the EEoA approach adds another dimension: affordability. The EEoA makes a clear distinction between the "lifecycle costs" or "price" of an alternative, its operational effectiveness (schedule and performance), and the resources (funding or budget) likely to be available for the overall program. By embedding affordability directly into an AoA, the EEoA

[3] According to the Government Accountability Office (GAO), over the next 5 years, the DoD plans to spend more than $357 billion on development and procurement of major defense acquisition programs (GAO, 2009, March 18, p. 4).

approach provides a unique opportunity for senior leadership to achieve a significant defense acquisition reform—to integrate Requirements Generation and Defense Acquisition with the Planning, Programming, and Budgeting System (PPBS), reducing future costs and improving performance and schedules.[4]

[4] The DoD's Planning, Programming, Budgeting and Execution (PPBE) process is the principal decision-support system used to provide the best possible mix of forces, equipment, and support within fiscal constraints. Two other major decision support systems complement the PPBE process: a Requirements Generation System to identify military investment opportunities and the Defense Acquisition System (DAS) to develop and procure new weapon systems.

THIS PAGE INTENTIONALLY LEFT BLANK

II. Integrating Requirements Generation, Defense Acquisition, and PPBS

In stressing affordability, the Economic Evaluation of Alternatives (EEoA) offers an analytical approach that addresses a major concern expressed by the US Government Accountability Office (GAO):

> DoD's processes for identifying war-fighter needs [Requirements Generation], allocating resources [Planning, Programming, and Budgeting System (PPBS)], and developing and procuring weapon systems [Defense Acquisition] are fragmented [so that] DoD commits to more programs than resources [budgets/funding] can support. [...] DoD allows programs to begin development without a full understanding [of] the resources [budgets/funding] needed. (2009 p.1)[5]

This observation is echoed in a recent study by BENS (Business Executives for National Security): "[R]equirements are largely determined […] *without adequate input as to what is* ***affordable*** *from a planning, programming, and budgeting perspective*" (2009, p. 10, emphasis added).

By embedding affordability directly into an AoA senior leadership has a unique opportunity to achieve a significant defense acquisition reform: to integrate the Requirements Generation System, Defense Acquisition System (DAS), and the Planning, Programming, and Budgeting System (PPBS). A brief overview of the DoD's budget development and acquisition systems highlights the valuable role affordability can play in structuring an EEoA.

[5] "The lack of early systems engineering, acceptance of unreliable cost estimates based on overly optimistic assumptions, failure to commit full funding, and the addition of new requirements well into the acquisition cycle all contribute to poor outcomes" (GAO, 2009, March 18, p.1). Whereas this study focuses on funding risks, Melese, Franck, Angelis and Dillard (2007, January) introduce an economic approach called "Transaction Cost Analysis" that addresses many of the other GAO concerns.

The primary purpose of PPBS is to make hard choices among alternative military capabilities and investments necessary for national security within fiscal constraints. The requirements generation process naturally fits into the Planning phase of PPBS. The first step in any investment analysis is to identify the derived demand for a key capability, program, or project. The focus of the EEoA is on materiel investments identified to fill critical capability gaps.[6] This is accomplished through the DoD's Requirements Generation System.

Operator demands ("requirements") are identified and refined in the Planning phase of the PPBE process. When a materiel solution is recommended, senior leaders identify prospective military investments that serve as the basis for AoAs that underpin the development of new acquisition programs in the Defense Acquisition System (DAS). Acquisition proposals (MDAP and MAIS) that emerge from the Planning process enter the DAS and are incorporated in the Programming phase of PPBE.

Ideally, the Planning phase of PPBE establishes fiscally constrained guidance and priorities for the military services, including readiness, sustainability and modernization. This guidance provides direction for the DoD Components (military departments and defense agencies) to develop their individual program and investment proposals, or Program Objectives Memorandum (POM). In this Programming phase of PPBE, the POMs detail resource-allocation decisions (funding, personnel, etc.) proposed by each Component for its programs, projected six years into the future. A challenge is that the DAS data needed to evaluate major

[6] Based on strategic-level guidance (the *National Security Strategy, National Military Strategy, Quadrennial Defense Review, Strategic Planning Guidance,* etc.), the requirements generation system reviews existing and proposed capabilities and identifies critical capability gaps. To fill those capability gaps, senior leadership examines the full range of "doctrine, organization, training, materiel, leadership and education, personnel and facilities (DOTMLPF)" (CJCS, 2007, p. A-1; USD (AT&L), 2008, p. 14). The DAS provides principles and policies that govern major defense acquisition decisions and milestones. To ensure transparency and accountability, and to promote efficiency and effectiveness, various instructions (e.g., *FAR, DFARS, DoD Directive 5000.01, DoD Instruction 5000.02*, etc.) specify statutory and regulatory reports (e.g., AoAs) and other information requirements for each milestone and decision point.

defense acquisition investments in an EEoA requires lifecycle cost estimates that project well beyond the six years of the POM.

Senior leadership in OSD and the Joint Staff subsequently review each Component POM to ensure it satisfies the Strategic Planning guidance and that it can be integrated into an effective and affordable overall national defense program. The Budgeting phase of PPBE occurs concurrently with the Programming phase.

The Budgeting phase converts the Programming phase's (output-oriented) view into the (input-oriented) format required by Congressional appropriation structures. While the DoD's biennial defense budget projects funding only two years into the future, it includes more financial detail than the POMs.[7] The Under Secretary of Defense Comptroller and the Office of Management and Budget (OMB) jointly review budget submissions to ensure programs are affordable, i.e., satisfy current fiscal constraints.[8]

The primary focus of Multi-criteria Decision-making (MCDM)—as traditionally applied in AoAs—is to estimate the lifecycle costs and operational effectiveness of alternative defense investments. "An AoA is an analytical comparison of the operational effectiveness…and Life-Cycle Cost of alternatives that satisfy established Capability needs" (DoD, 2006, July 7, Section 3.3). This paper emphasizes another key aspect: Affordability.

---

[7] By translating the budget implications of these decisions into the usual Congressional appropriation categories (Military Personnel, Procurement, Operations & Maintenance (O&M), Military Construction, etc.), decision-makers are able to generate the defense budget and Future Year Defense Program (FYDP).

[8] *Office of Management and Budget (OMB) Circular A-11*, titled *Preparation and Submission of Budget Estimates*, is the official guidance on the preparation and submission of budget estimates to Congress. The Army's Acquisition guidance emphasizes "the requirement for presenting the full funding for an acquisition program—that is the total cost [for] a given system as reflected in the most recent FYDP […] pertains to all acquisition programs" (DoA, 1999, July 15, p. 41).

In helping generate investment alternatives and illuminating the benefits and costs of those alternatives, AoAs have the potential to contribute to requirements generation in the Planning phase of PPBE and, through DAS decision milestones, could also influence the Programming phase of PPBE. However, according to the GAO: "[T]he vast majority of capability proposals that enter the JCIDS [Requirements Generation] process are […] approved without accounting for resources [funding/budgets] that will be needed to acquire the desired capabilities" (GAO, 2009, p. 6).[9] The concern for the availability of resources or future affordability is a primary focus of this paper.

The EEoA approach represents an important step in the long-running effort to integrate the DoD's Requirements Generation and Defense Acquisition Systems with PPBE. In considering alternative budget scenarios that rely on FYDP forecasts, policy-makers can use the EEoA to inject an explicit, constrained optimization approach into defense acquisition investment decisions that parallels one already embedded in PPBE—choosing an optimal mix of forces, equipment and support that maximizes national security subject to fiscal constraints.

[9] "A 2008 DoD directive established nine joint capability-area portfolios, each managed by civilian and military co-leads […]. However, without […] control over resources [funding/budgets], the department is at risk […] of not knowing if its systems are being developed within available resources [funding/budgets]" (GAO, 2009, March 18, p. 11).

III. Embedding Affordability Assessments into AoAs

A serious concern expressed by the GAO and others is that military requirements are often approved without fully accounting for resources available, i.e., ignoring future funding or budget realities. This reflects a fundamental weakness in the way AoAs have traditionally been structured. While decision-makers use AoAs to estimate the costs and effectiveness of competing alternatives, affordability is often addressed as a separate exercise, and then only ex-post.[10] This is reflected in GAO's concern that "at the program level, the key cause of poor outcomes is the approval of programs with business cases [AoAs] that contain inadequate knowledge about […] resources [i.e. funding] needed to execute them" (2009, p. 7). Ironically, this directly contradicts the defense department's own policy outlined in the *DoD Directive 5000.01*, which explicitly states: "All participants in the acquisition system shall recognize the reality of fiscal constraints […]. DoD components shall plan […] *based on realistic projections of the dollars […] likely to be available* [and] the user shall address ***affordability*** in establishing capability needs" (USD (AT&L), 2007, p. 5, emphasis added).

Current DoD directives require that an AoA be performed at key milestone decision points (i.e., A, B, C) for all Major Defense Acquisition Programs (MDAP) and Major Acquisition Information Systems (MAIS). Affordability assessments (a separate exercise) are only required at Milestones B and C (USD (AT&L), 2008, December 8, p. 40). The Economic Evaluation of Alternatives (EEoA) offers a mechanism to embed affordability assessments into AoAs as early as Milestone A.

[10] "Typically, the last analytical section of the AoA plan deals with the planned approach for the cost-effectiveness comparisons of the study alternatives" (DoD, 2006, July 7, Section 3.3). Note that there is no mention of "affordability," but instead only an ex-post cost-effectiveness trade-off that implies a concern for affordability. Moreover, this trade-off occurs at the end of a process in which alternatives under consideration have been developed independently of any cost/budget/funding/affordability constraint. The US Marine Corps (PA&E) has a similar approach to structuring an AoA.

According to the *Defense Acquisition Guidebook*, the purpose of an affordability assessment is to demonstrate that a program's projected funding requirements are realistic and achievable.[11] "In general, the assessment should address program funding over the six-year programming [FYDP] period, and several years beyond. The assessment should also show how the projected funding fits within the overall DoD Component plan" (DoD, 2006, July 7, Section 3.2.2).[12] In preparing affordability assessments, one possible source of data decision-makers can use is the Future Years Defense Program (FYDP).[13] The EEoA provides a mechanism for analysts and decision-makers to embed affordability assessments directly into AoAs.

[11] Since this assessment requires a DoD Component corporate perspective, the affordability assessment should not be prepared by the program manager, nor should it rely too heavily on the user. It requires a higher-level perspective capable of balancing budget trade-offs (affordability) across a set of users (DoD, 2006, July 7, Section 3.2.2).

[12] A first step in the program's affordability assessment is to portray the projected annual modernization funding (RDT&E plus procurement, measured as TOA) in constant dollars for the six-year programming period and for twelve years beyond. Similar funding streams for other acquisition programs in the same mission area also would be included. What remains to be determined is whether this projected funding growth is realistically affordable relative to the DoD Component's most likely overall funding. The model in this study proposes structuring the Economic Evaluation of Alternatives not only for a "most likely" budget but also for an "optimistic" and "pessimistic" budget.

13 An output of the DoD's PPBE process, the Future Year Defense Plan (FYDP) is an Office of the Secretary of Defense (OSD) database that contains future budget projections.

IV. An Intuitive Guide to the Economic Evaluation of Alternatives (EEoA)

In order to nest the Requirements Generation and Defense Acquisition Systems within PPBE, decision-makers can formulate the military's acquisition problem in terms of identifying and funding investments that maximize value (performance or effectiveness) for a given budget. By structuring the military investment problem as a constrained optimization—i.e., maximizing effectiveness subject to a budget constraint (or alternatively minimizing costs of obtaining a given level of effectiveness)[14]—decision-makers would boost the value of an AoA since it now directly relies on higher-level resource-allocation decisions in the Planning and Programming phases of PPBE.

Unfortunately, MCDM techniques typically applied to structure AoAs do not lend themselves to this interpretation. As a consequence, rather than being constrained by budgets, budgets are typically the output of an AoA, generating so-called "funding requirements."[15] The third approach to structuring an EEoA turns this on its head. Instead of generating a budget through the AoA process, decision-makers or analysts forecast an optimistic, pessimistic, and most-likely budget as part of the PPBE process and then challenge vendors to propose alternatives that fit

---

14 These dual-constrained-optimization approaches represent the first two of six ways proposed in this study to structure an Economic Evaluation of Alternatives (EEoA).

[15] A recent Senate Report states that "Awards are made on the basis of the solicitation of factors and sub-factors by a Source Selection Official who, using his or her discretion and independent judgement [e.g., guided by an AoA], makes a comparative assessment of […] competing proposals, trading off relative benefits and costs" (Chapter 1, Commercial Practices, p. 65). The Senate Committee's recommendation is that "Regulatory guidance […] be provided in FAR to [include] a minimum weight to be given to cost/price" (p. 102). Missing in this discussion is an explicit and realistic acknowledgement of "affordability"—the resources, funding, or budgets available for the procurement—something only indirectly and implicitly addressed in assigning a "weight" to cost (see Section 2 of this study).

within that budget envelope.[16] This offers an approach to Defense investment decisions based on explicit funding (resource/budget/affordability) scenarios that supports the "long-standing DoD policy to seek full funding of acquisition programs" (DoD, 2006).

According to the *Defense Acquisition Guidebook*, affordability assessments should also provide details as to how excess funding demands will be accommodated by reductions in other mission areas or in other accounts.[17] This opportunity-cost approach is an illustration of the last of six ways identified in this study to structure an EEoA.

Whereas funding decisions for major programs take place through the PPBE process, the GAO finds that "the process does not produce an accurate picture of the department's resource needs [funding/budget requirements] for weapon system programs [...]. Ultimately, the process produces more demand for new weapon system programs than available resources can support"[18] (Sullivan, 2009, March 18, p. 6).

The EEoA approach directly responds to these challenges. It also responds to other concerns highlighted by the GAO that continue to confront the DoD's Defense

---

[16] This is in the spirit of the Department of the Army's Acquisition Procedures, which explicitly states that "Cost as an Independent Variable (CAIV) applies to all defense acquisition programs [… and] treats cost as an input to, rather than an output of, the materiel requirements and acquisition processes" (DoA, 1999, p. 63). The Army guidance emphasizes "CAIV is focused on […] meeting operational requirements with a solution that is affordable [… and that does] not exceed cost constraints [and to] establish CAIV-based cost objectives (development, procurement, and sustainment costs) early in the acquisition process" (p. 63). Moreover, the "RFP must […] solicit from potential suppliers an approach […] for meeting CAIV objectives" (p. 63).

[17] Note that in the off-year of the biennial PPBE process, the DoD Components are restricted to the second year of the biennial budget and are required to submit Program Change Proposals (PCPs) and/or Budget Change Proposals (BCPs) to account for any program-cost increases, schedule delays, etc. PCPs address issues over a multi-year period, whereas BCPs address issues focused on the upcoming budget year. Moreover, to stay within fiscal constraints, BCPs and PCPs must identify resource reductions in other programs to offset any cost growth. This is similar in spirit to the opportunity-cost approach that is one of the six ways proposed herein to structure an EEoA.

[18] The cost of many programs reviewed by the GAO exceeded planned funding/budget levels (GAO, 2008, July 2).

Acquisition System, including: “(1) [to make] better decisions about which programs should be pursued or not pursued given existing and expected funding; [and] (2) [to develop] an analytical approach to better prioritize capability needs” (Sullivan 2009, March 18).

In generating alternatives under optimistic, pessimistic and most-likely budget scenarios, the EEoA requires explicit interaction with the PPBE process. In sharp contrast with the MCDM approach that underlies most AoAs, the EEoA explicitly identifies and emphasizes budget and funding constraints or “affordability.” Widespread adoption of the EEoA would contribute to the goal of:

> greater consultation between requirements, budget, and acquisition processes [that] could help improve the department’s […] portfolio of weapon programs […]. This means that decision makers responsible for weapon system requirements, funding, and acquisition execution must establish an investment strategy in concert […], assuring requirements for specific weapon systems are clearly defined and achievable given available [funding/budget] resources. (GAO, 2008, July 2, pp. 10, 14)

The next section offers a brief description and critical evaluation of the status quo. Two common decision criteria used in cost-effectiveness analyses are discussed. The first is the popular “bang-for-the-buck” or benefit/cost ratio. The second criterion involves a familiar controversy that surrounds the choice of an appropriate weight to assign to cost. This weighted-average-of-cost-and-effectiveness decision rule originates from the standard static, deterministic MCDM approach to cost-effectiveness analysis that underpins most contemporary AoAs. Section 6 illustrates six alternative recommended approaches to structure an Economic Evaluation of Alternatives (EEoA).[19] The final section concludes with a Decision Map to guide analysts and decision-makers in selecting which of the six approaches is best suited to their circumstances.

[19] An appendix is available upon request that reveals the static, deterministic, multi-stage, constrained-optimization, micro-economic production (procurement auction) model that underpins the central EEoA approach.

THIS PAGE INTENTIONALLY LEFT BLANK

V. A Critical Evaluation of the Status Quo: Two Popular Decision Criteria

Today, most modern military investment (and disinvestment) decisions are supported by some form of cost-benefit analysis (CBA). The US DoD applies CBA to anything from milestone decisions for Major Defense Acquisition Programs (MDAPs and MAISs), to outsourcing (OMB, 2003, May 29; Eger & Wilsker, 2007), to public-private partnerships, privatization, or Base Realignment and Closure (BRAC) actions (see OMB Circular A-94; FAR; DFARS; DoD 5000 series, etc.).

When benefits cannot be expressed in monetary terms, analysts develop so-called "measures of effectiveness" (MOEs), in which case CBA is generally referred to as cost-effectiveness analysis (OMB, 1992, October 29).[20] The most common methodology and approach for building MOEs and structuring cost-effectiveness analyses is alternately referred to as Multiple-criteria Decision-making (MCDM), Multi-attribute Utility Theory (MAUT), or Multiple-objective Decision-making (MODM) (see French (1986); Keeney and Raiffa (1976); Clemen (1996); Kirkwood (1997); Parnell (2006); Ramesh & Zionts (1997); etc.).

This paper describes some limitations with the current decision criteria used in most AoAs and proposes an alternate methodology derived explicitly from the constrained-optimization approach recommended for an EEoA. The latter approach is closer in spirit to the economic origins of cost-effectiveness analysis in Gorman (1980), Hitch and McKean (1967), Michael and Becker (1973), Stigler (1945), Theil (1952); etc., but is most often attributed to Lancaster (1966a; 1966b; 1971; 1979). A key difference between the MCDM approach to an AoA and an EEoA is that instead

[20] Fisher (1965) argues that "numerous terms […] convey the same general meaning […] 'cost-benefit analysis,' 'cost-effectiveness analysis,' 'systems analysis,' 'operations analysis,' etc. Because of such terminological confusion, […] all of these terms are rejected and 'cost-utility analysis' is employed instead" (p. 185). Although this study uses the terms "cost-benefit" and "cost-effectiveness" interchangeably, the assumption throughout is that neither benefits nor effectiveness can be measured in monetary terms.

of modeling decision alternatives from competing vendors as points in cost-effectiveness space, the EEoA models alternative vendor proposals as functions of optimistic, pessimistic, and most-likely funding (resource/budget) scenarios.

The EEoA approach directly responds to the GAO's observation that affordability needs to be an integral part of any business case (AoA): "Our body of work on best practices has shown that an executable business case is one that provides demonstrated evidence that…the chosen concept can be developed and produced within existing resources—that is…funding…" (GAO, 2010, Jan 20, p. 2). Benchmarking against the private sector, the GAO emphasizes that "successful commercial enterprises […] follow a disciplined integrated process during which the pros and cons of competing proposals are assessed based on strategic objectives […] and available [budget/funding] resources" (GAO, 2009, March 18, p. 5).

A distinctive feature of defense investment decisions is that multiple criteria such as cost and effectiveness cannot easily be combined into a single, overall objective such as "government profitability." The problem of ranking public investments when benefits cannot be expressed in dollars has spawned an extensive literature in management science, operations research and the decision sciences.

This literature models investment alternatives as bundles of measurable characteristics (attributes or criteria). Techniques that mostly fall under the umbrella of MCDM are routinely used by analysts and decision-makers (e.g., through AoAs) to guide public investment decisions. The development of Measures of Effectiveness (MOEs)[21] and lifecycle cost calculations are used to help rank alternatives. An ongoing concern is how to integrate costs and effectiveness in the final selection

[21] The Defense Acquisition Guidebook Section 3.3.1: AoA Plan states that "measures of effectiveness […] provide the details that allow the proficiency of each alternative in performing the mission tasks to be quantified […]. A measure of performance typically is a quantitative measure of a system characteristic (e.g., range, […] logistics footprint, etc.) chosen to enable calculation of one or more measures of effectiveness" (DoD, 2006, July 7).

process (see Henry and Hogan (1995); Melese and Bonsper (1996, December); Melese, Stroup, and Lowe (1997); etc.).

In their pioneering work applying economic analysis to defense, Hitch and McKean (1967) define a "criterion" as the "test by which we choose one alternative […] rather than another" (p. 120). They stress that "[t]he choice of an appropriate economic criterion is […] the central problem in designing a [cost-effectiveness] analysis" (p. 158).

The two most popular decision criteria used to integrate cost and effectiveness in AoAs are 1) to construct Benefit/Cost (or MOE/Cost) ratios, and 2) to assign a weight on cost relative to effectiveness and construct a weighted average of cost and effectiveness (using a linear, separable, additive "value" function). The latter decision criterion is a common prescription for AoAs that emerges from MCDM. Both approaches, however, are problematic. We first focus on what is arguably the most commonly applied criterion: benefit/cost ratios. Next, we move to the most common MCDM decision criterion: assigning a relative weight to the cost (price) of alternatives in an overall value function. At first glance, the Benefit/Cost (MOE/Cost) ratio or "bang-for–the-buck" criterion is appealing. However, it turns out to be largely meaningless unless alternatives are constructed for a specific budget (funding/affordability) scenario or to achieve a specific level of effectiveness. Meanwhile, the second decision criterion also turns out to be misleading in the absence of a specific budget (funding/affordability) scenario and a good understanding of opportunity costs.[22]

[22] Ironically, if a budget scenario is specified, there is no need to take the MCDM approach that underpins most AoAs, since it is possible to adopt the EEoA approach. The EEoA approach constructs alternatives to fit within a budget envelope, converting the problem into a straightforward MOE maximization (see Section 6).

A. Bang-for-the-Buck (Benefit/Cost or Effectiveness/Cost) Ratios

It is well known that the application of a benefit/cost ratio (or bang-for-the-buck) decision criterion to rank alternatives is largely meaningless unless alternatives are constructed for a specific budget (funding) scenario, or to achieve a specific level of effectiveness. Yet, the next three examples illustrate that this continues to remain a popular decision criterion in the absence of budget or effectiveness constraints.

1. In a military text entitled *Executive Decision Making*, the author offers that "[w]hen we cannot fix cost or effectiveness, we might combine them to help us choose between alternatives […]. If neither can be fixed […] we can establish a cost/effectiveness ratio" (Murray, 2002, p. 6-3, 6-10).

2. In presenting what they claim is a "novel cost-benefit analysis" for the "comprehensive evaluation of competing military systems," Byrns, Corban and Ingalls (1995) in their article in the *Acquisition Review Quarterly* define a "merit function" as "a single number […] [that] reflects the ratio of benefits derived to dollars spent" (i.e., a benefit/cost ratio). They assert: "with this […] approach, the cost effectiveness of competing systems can be compared and "provides for objective and reliable decision making," where "a large system merit [benefit/cost ratio] is preferable to a small one" (p.2&4).

3. Similarly, in a section entitled *Comparing Costs and Benefits*, the Department of the Army's *Economic Analysis Manual* states: "When the results yield unequal cost and unequal benefits […], all alternatives

[…] may be ranked in decreasing order of their benefit/cost ratios" (DoA, 2001, February, p. 32).[23]

Each of these examples recommends using a benefit/cost ratio as the decision criterion. Each also neglects including either an affordability constraint (keeping the level of cost fixed), or a performance constraint (keeping the level of effectiveness fixed). Unfortunately, a noted RAND analyst, the legendary Gene Fisher (1971), clearly points out in his classic text *Cost Considerations in Systems Analysis*:

> The use of [benefit/cost] ratios usually poses no problem as long as the analysis is conducted in [a] framework […] with the level of effectiveness or cost fixed. However, it is common to encounter studies where this has not been done, with the result that the comparisons [are] essentially meaningless. (p. 11)

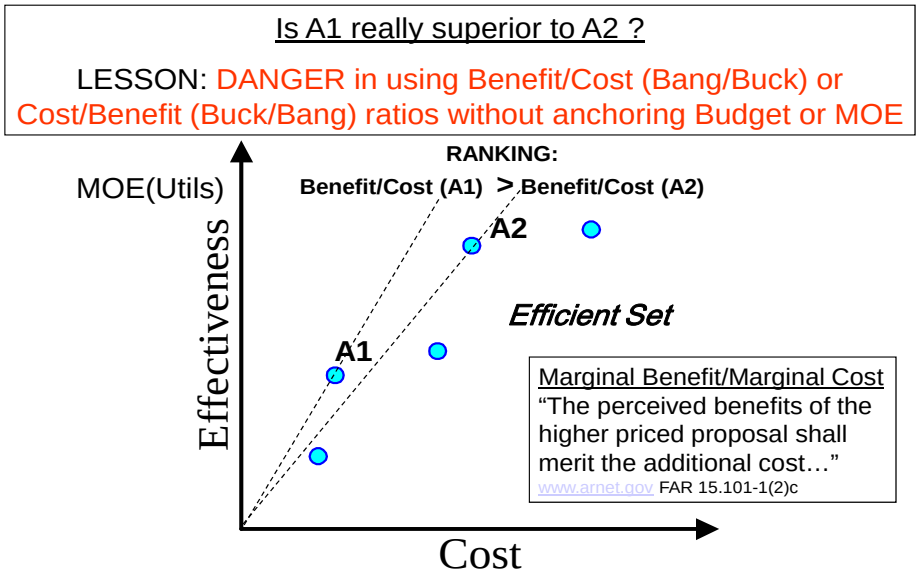


Figure 1. Inappropriate Application of Benefit/Cost Ratios

[23] A fourth example involves a recent landmark RAND study on Capabilities-based Planning. The author falls into the same trap. In a section entitled *Choosing Among Options in a Portfolio*, Paul Davis (2002) develops "A Notional Scorecard for Assessing Alternatives in a Portfolio Framework," where alternatives differ in both their costs and effectiveness. Nevertheless, the decision criterion recommended by the author to select an alternative in "[t]he last column is the ratio of effectiveness over cost" (p. 45-46).

A simple, extreme example helps illustrate the danger in using benefit/cost ratios without anchoring either the budget or a specified Measure of Effectiveness (MOE). Suppose Alternative A1 in Figure 1 costs $10 million and yields an MOE of 10 utils while Alternative A2 costs $1 billion and yields an MOE of 900 utils.[24] Applying a benefit/cost ratio criterion indicates that A1 has a bigger bang-for-the-buck since it returns 1 util per million dollars, while A2 only offers 0.9 utils per million dollars.

However, using benefit/cost ratios to rank alternatives is dangerous in this case because it ignores the absolute magnitude of the costs involved. Suppose the situation was reversed, and A2 offered a higher benefit/cost ratio than A1. Anyone that ignores affordability and chooses A2 strictly on the basis of bang-for-the-buck would be in for an unpleasant surprise (a $1 billion versus a $10 million decision).

Since affordability and opportunity costs are always a concern in public investment decisions (especially through the Requirements Generation System, Defense Acquisition System, and PPBS), it is imperative that analysts and decision-makers explore budget and opportunity cost implications of going with the high-cost alternative (for example, the extra $990 million to obtain an additional 890 utils of MOE) or, equivalently, of the savings in going with the low-cost alternative.

In applying economic analysis to defense, Hitch and McKean (1967) warn:

> One common “compromise criteria” is to pick that [alternative] which has the highest ratio of effectiveness to cost. [M]aximizing this ratio is the [decision] criterion. [While] it may be a plausible criterion at first glance […] it allows the absolute magnitude of [effectiveness] or cost to roam at will. In fact, the only way to know what such a ratio really means is to tighten the constraint until either a single budget (or particular degree of effectiveness) is specified. And at that juncture, the ratio reduces itself to the test of maximum effectiveness

[24] In Figure 1, the slope of any ray from the origin represents a constant benefit/cost ratio anywhere along that ray. The steeper the slope, the greater the benefit/cost ratio.

> for a given budget (or a specified effectiveness at minimum cost), and might better have been put that way at the outset. (pp. 165-167)[25]

The Economic Evaluation of Alternatives (EEoA) approach follows this advice and other key recommendations made by Hitch and McKean (1967):

> The test of maximum effectiveness for a given budget (or alternatively, minimum cost of achieving a specified level of effectiveness) […] seems much less likely to mislead the unwary. (p.167)

> As a starter […] several budget sizes can be assumed. If the same [alternative] is preferred for all […] budgets, that system is dominant […]. If the same [alternative] is not dominant the use of several […] budgets is nevertheless an essential step, because it provides vital information to the decision maker. (p. 176)

The conclusion is straightforward. The use of benefit/cost ratios as a decision criterion in AoAs does not pose a problem as long as the analysis is structured in a way that pays close attention to affordability (i.e., for a fixed budget (funding/affordability level)), or performance (i.e., for a fixed level of effectiveness (MOE)).[26] Since AoAs typically consider alternatives that differ in both their costs (price) and benefits (MOEs), the use of benefit/cost (or effectiveness/cost) ratios to rank alternatives is at best "misleading."[27] Partly as a consequence, decision scientists developed another decision criterion—Multi-criteria Decision-making (MCDM)—to rank investment options; MCDM is routinely applied in AoAs. This second popular decision criterion is examined below.

---

[25] The authors continue: "Of course, if the ratios did not alter with changes in the scale of achievement (or cost, the higher ratio would indicate the preferred system, no matter what the scale […]. But to assume that such ratios are constant is inadmissible some of the time and hazardous the rest" (Hitch & McKean, 1967, p. 167).

[26] An additional (necessary and sufficient) condition is a linear, separable, additive objective function.

[27] "Usually, ratios are regarded as potentially misleading because they mask important information" (DoD, 2006, July 7, Section 3.3.1).

B. Weighted Averages of Cost and Effectiveness: Assigning a Weight to Cost

MCDM is often used as an umbrella term, and that is how it will be used in this study. “In the literature the terms multi-attribute decision making (MADM), multi-criteria decision making (MCDM), and multi-objective decision making (MODM) are used almost interchangeably” (French, 1986, p. 105). In a typical MCDM evaluation, a decision-maker (DM) is asked to identify desired attributes (criteria/characteristics) of a project, program or system to fill some critical capability gap given a specific threat scenario. Next, the DM is asked to reveal agreeable trade-offs among those attributes. An exercise of this sort helps analysts uncover the DM’s underlying trade-offs, or their “utility” function, to generate a Measure of Effectiveness (MOE) for each alternative.[28]

To uncover a DM’s utility function, decision scientists beginning with Saaty (1977) bridged an important implementation gap. Multiple objective (analytic) hierarchy approaches were developed to help reveal underlying utility functions. For example, an objectives hierarchy can help a DM work down from a high-level objective (provide national security) to a relevant set of sub-objectives (an effective airlift capability), to specific attributes (mobility, transportability, etc.) and, finally, to measurable characteristics (Mobility = speed (S), range (R); transportability = payload (P), weight (W), etc.). The outcome in this example is a utility function for airlift capability: U=U(M(S,R);T(P,W)), where the characteristics might be measured respectively in mph, miles, cubic feet, and pounds.

[28] “Measures of Effectiveness […] provide the details that allow the proficiency of each alternative in performing the mission tasks to be quantified […]. A measure of performance typically is a quantitative measure of a system characteristic (e.g., range, etc.) chosen to enable calculation of one or more measures of effectiveness […]. The cost analysis normally is performed in parallel with the operational effectiveness analysis. It is equal in importance in the overall AoA process […]. [I]ts results are later combined with the operational effectiveness analysis to portray cost-effectiveness comparisons” (DoD, 2006, July 7, Section 3.3.1)

The standard assumption in the literature is to define a linear, separable, additive utility function that generates an MOE for each alternative—roughly analogous to a weighted average of its attributes—provided certain assumptions are satisfied, such as "preferential independence," etc. (see French (1986); Keeney and Raiffa (1976); and Keeney (1994)). There is a vast literature concerned with eliciting preference weights and the normalization of characteristics data that involves several important issues reserved for future research.[29]

Temporarily overlooking these issues, it is interesting to note in passing that maximizing a linear multi-attribute utility function subject to a budget (affordability) constraint yields a decision rule analogous to the benefit/cost ratio criterion discussed above. Under the assumption of a fixed budget and linear, additive, separable utility function, the benefit/cost decision rule can be used to rank alternatives. In this case, the winning alternative is the one that generates the highest MOE per dollar or the biggest bang-for-the-buck. With a more general (non-linear) utility function, the equivalent optimization generates a more complex, marginal benefit/marginal cost decision rule.

In reality, MCDM techniques that underpin the configuration of the fundamental decision problem in most AoAs do not rely on an explicit discussion of budgets, affordability, or funding (resource constraints) . As a consequence, the problem is typically not structured as described above.

Instead of structuring an AoA as a constrained optimization, a popular decision-analysis approach is (towards the end of an AoA) to simply attach a weight

[29] For example, one issue is that normalization of attributes is not necessary, and worse, can be misleading. The author is aware of several applications in which relative weights were assigned to different attributes based on soliciting acceptable trade-offs among *measurable characteristics* from decision-makers but were then later applied to the *normalized values* of the characteristics to obtain MOEs (personal correspondence with DoD officials).

to cost and introduce it directly into the utility function.[30] As opposed to a benefit/cost (or effectiveness/cost) ratio, this popular MCDM approach generates an overall "value" function that is essentially a weighted average of cost and effectiveness.

In effect, alternatives are ranked and selections are made by Decision-Makers through an unconstrained optimization shaped by analysts, where the best alternative is the one that maximizes the overall effectiveness or value function V = V(MOE; COST). "Deterministic decision analysis is concerned with finding the most preferred alternative in decision space by constructing a value function representing a decision maker's preference structure, and then using the value function to identify the most preferred solution" (Ramesh & Zionts, 1997, p. 421). The linear, additive, separable version of this value function is frequently used to calculate a positively weighted MOE and negatively weighted cost for each alternative. For example, see Beil & Wein (2003), Che (1993), Clemen (1996), Kirkwood (1997), French (1986), Keeney & Raiffa (1976), Keeney (1994), Hwang and Yoon (1981), Liberatore (1987), Pinker, Samuel, and Batcher (1995), Varzsonyi (1995), etc.

The typical decision sciences' (MCDM) approach to an AoA[31] involves:

Given several alternatives, select the preferred alternative that provides the best value, or maximizes: V(MOE,COST) = w1***MOE** - w2***COST**

This requires two important modeling efforts: 1) building an effectiveness (MOE) model (non-cost factors; performance = quality, schedule, etc.); and 2) building a cost model (costs/prices; estimate total system lifecycle costs, total ownership costs). Once these independent modeling efforts are completed, the overwhelming

---

[30] "In the European Union, a legislative package intended to simplify and modernize existing public procurement laws was recently adopted. As before, the new law allows for two different award criteria: lowest cost and best economic value. The new provisions require that the procurement authority publishes ex-ante the relative weighting of each criteria used when best economic value is the basis for the award" (see EC, 2004a; 2004b).

[31] "An AoA is an analytical Comparison of the operational Effectiveness, suitability, and Life-Cycle Cost of Alternatives that satisfy established Capability needs" (DoD, 2006, July 7).

challenge is to integrate the two by using either benefit/cost ratios (discussed earlier) or by assigning a relative weight to cost (a value for w2 in the example above).

The typical recommendation in the applied literature to integrate cost and effectiveness is for analysts to ask the DM: "How important is cost relative to effectiveness?" The *Federal Acquisition Regulation (FAR)* supports this approach: "The solicitation shall state whether all evaluation factors other than cost/price, when combined [i.e., MOE], are significantly more important than, approximately equal to, or significantly less important than cost/price" (General Services Administration, 2005, March, Section 15.101-1(2)). The Office of Management and Budget (OMB)[32] also promotes this approach: "The specific weight given to cost or price shall be at least equal to all other evaluation factors combined unless quantifiable performance measures can be used to assess value and can be independently evaluated" (OMB, 2003, p. B-8). The decision regarding the appropriate relative weight to assign to costs is a hotly debated and contentious issue that has resulted in bid protests being sustained by the GAO. (See Melese et. al. 2010)

A key proponent of this (MCDM) decision methodology offers an example of administrators who are evaluating alternative pollution control devices being asked to answer questions such as "Which is more important, costs or pollutant concentrations?" (Keeney, 1994, p. 797). As the author is quick to point out, the problem with this approach is that without some estimate of the total budget available or any knowledge of opportunity costs, one cannot expect the DM to provide a sensible answer. Ironically, that same author--one of the strongest

[32] According to the FAR, "source selection" is the decision process used in competitive, negotiated contracting to select the proposal that offers the "Best Value" to the government. "In different types of acquisition, the relative importance of cost or price may vary" (General Services Administration, 2005, Section 15.101). In describing some lessons learned, Gansler (2003) recommended: Use performance-based contracting; Do not list tasks [mix of inputs], instead state results sought or problems to be solved [desired attributes/characteristics of outputs/outcomes]; Choose contractors according to "Best Value"; In the source selection, trade off performance and price instead of simply awarding to the lowest bidder (p. 15).

proponents of this methodology--warns: “I personally do not want some administrator to give two minutes of thought to the matter and state that pollutant concentrations are three times as important as cost”[33] (Keeney, 1994, p. 797).

Figures 2 and 3 offer an illustration. Figure 2 reflects a situation in which the decision-maker believes costs to be important enough (and thus assigns a sufficiently large relative weight, w2/w1, to cost) that the preferred alternative is A1 (the low-cost option). The opposite case is illustrated in Figure 3.[34]

How does a decision-maker (DM) decide on an appropriate weight to assign to costs? Consider an extreme case. Suppose affordability is not an issue, so funding is not an issue. In that case, the budget is not binding, making costs irrelevant. Clearly, this means a zero weight should be assigned to costs, and the alternatives can be ranked exclusively on the basis of their MOEs (e.g., A2 wins). As a consequence, any weight (w2) applied to costs must reflect an implicit concern about affordability (budgets/funding levels).

A key hypothesis in the Economic Evaluation of Alternatives (EEoA) is that if a DM pays any attention to costs (i.e., places a weight on cost), it is because he/she acknowledges an implicit affordability or budget constraint or recognizes there may be some opportunity cost for funds committed to the program. This is directly related to the higher-level affordability discussions in Section 1 that included Requirements Generation, Defense Acquisition, and PPBE.[35]

---

[33] Surprisingly, the author has continued to write prolifically in this field and continued to promote this decision criterion, apparently never taking the time to reflect back on these key observations.

[34] Note that the slope of the straight-line indifference curves reflect the DM’s relative preference (or trade-offs). These trade-offs between MOE and Cost are given by –w2/w1.

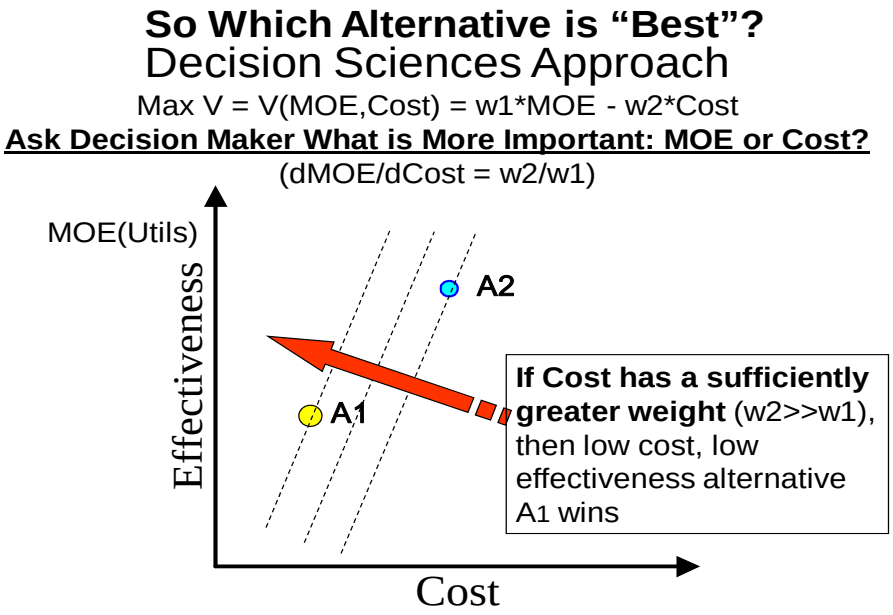


Figure 2. When Cost Is Relatively More Important than Effectiveness

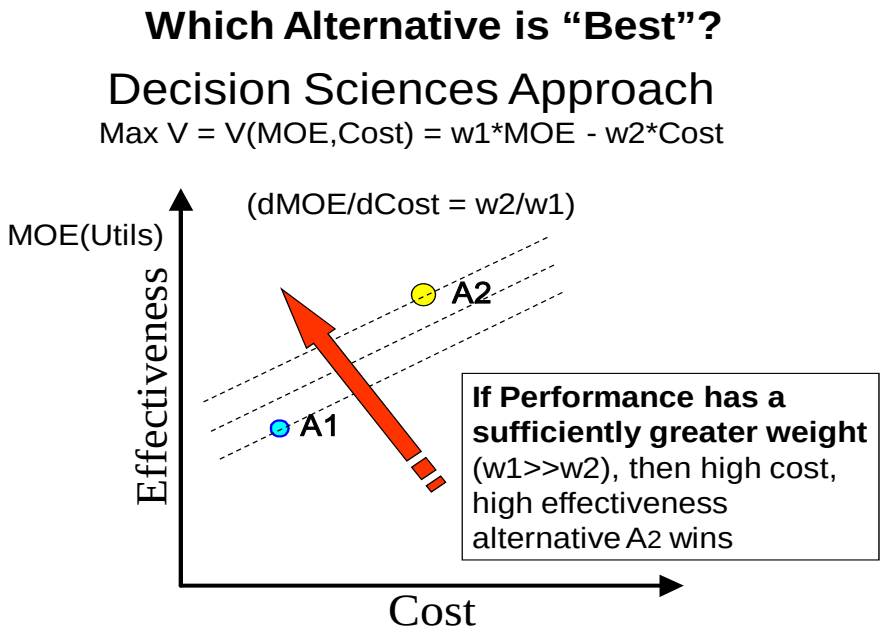


Figure 3. When Effectiveness Is Relatively More Important than Cost

---

[35] The Army's Economic Analysis (EA) Manual states that "[a] good EA should go beyond the decision-making process and become an integral part of developing requirements in the PPBE process" (DoA, 2001, February, p. 12).

The irony, as Keeney (1994) rightly observed, is that to assign any weight to costs requires the DM to have some understanding of affordability (why would you care about costs unless there are constraints on the budget/funding/resources available?) and an appreciation of relevant opportunity costs. But if this information is known, then analysts and decision-makers have no reason to take the MCDM approach and assign a weight to costs since the more robust, constrained-optimization (mathematical programming) EEoA approach is available.

In fact, it is relatively straightforward to demonstrate that even if the DM had perfect information about the budget (funding/affordability) and attempted to interpret that information through a weight assigned to the relative cost (price) of alternatives (as illustrated in Figures 2 and 3), the rankings that resulted would only coincidentally correspond to rankings obtained under the full-information-constrained-optimization EEoA (in which MOE is maximized subject to the budget constraint).[36]

This is a damning result that clearly undermines the way MCDM is typically applied by analysts to support AoAs. If there is no guarantee that the MCDM approach will yield consistent results under full information (including affordability), then using this criterion with less-than-perfect information (i.e., in the absence of explicit assumptions about affordability/budgets/funding) is clearly problematic. In fact, the GAO emphasizes that "[w]ith high levels of uncertainty […] funding needs are often understated" (GAO, 2009, p. 9). A very real risk in applying the MCDM approach is that if AoAs "fail to balance needs with resources [funding/budgets] […] un-executable programs [are allowed] to move forward, [and] program managers […] are handed […] a low probability of success" (GAO, 2009, p. 10).

[36] The weight on cost in the unconstrained optimization (MCDM approach) roughly corresponds to the Lagrangian multiplier (shadow price) of the budget constraint in the constrained optimization (the EEoA approach).

In conclusion, the popular MCDM decision sciences approaches that underpin most AoAs either: i) explicitly ignore affordability in applying the benefit/cost (effectiveness/cost) ratio criterion,[37] or ii) implicitly attempt to capture affordability by choosing a relative weight to assign to cost, maximizing gains and minimizing costs in a value function such as: Maximize V = V(MOE,Cost) = w1*MOE - w2*Cost.[38] Again, to quote Hitch and McKean (1967):

> One ubiquitous source of confusion is the attempt to maximize gain [w1*MOE] while minimizing cost [w2*Cost] […]. If a person approaches a problem with the intention of using such a [decision] criterion, he is confused to begin with […]. [A] criterion in which the budget [affordability] […] is specified has the virtue of being aboveboard. (pp. 165-167)

Rather than attempt to get a DM to implicitly reveal his or her affordability concerns through a weight assigned to costs (prices) of alternatives, the Economic Evaluation of Alternatives (EEoA) recommends an explicit, transparent and accountable approach: treat cost as an independent variable (CAIV). The relevant CAIV concept applied here follows a definition posted on the Office of the Under Secretary of Defense (Acquisition & Technology) website in early 1999. It states that CAIV is: "DoD's acquisition methodology […] making […] performance a function of ***available budgeted resources***" (see Lorell & Graser, 2001, p. 33). The *Office of Management and Budget (OMB) Circular A-109* for Major Systems Acquisition mentions the goal of "design-to-cost." According to the *Defense Acquisition Guidebook,* "all participants […] are expected to recognize the reality of fiscal

---

[37] "One common 'compromise criteria' is to pick that [alternative] which has the highest ratio of effectiveness to cost. [M]aximizing this ratio is the [decision] criterion. [While] it may be a plausible criterion at first glance […] it allows the absolute magnitude of [effectiveness] or cost to roam at will. In fact, the only way to know what such a ratio really means is to tighten the constraint until either a single budget (or particular degree of effectiveness) is specified" (Hitch & McKean pp. 165-167).

[38] In a section describing *Building a Model*, Fisher (1965) comments: "Since by definition a model is an abstraction from reality, the model must be built on a set of assumptions. These assumptions must be made explicit. If they are not, this is to be regarded as a defect of the model design" (p. 190). It is easy to conceal the importance of affordability (budget/funding) issues in the MCDM, decision sciences approach that underpins many AoAs. In sharp contrast, the Economic Evaluation of Alternatives approach encourages explicit affordability (budget/funding) assumptions.

constraints" (DoD, 2006, July 7, Section 3.2.4). It is clear from these examples that CAIV is directly concerned with affordability.[39] The next section illustrates how affordability is explicitly incorporated in the Economic Evaluation of Alternatives (EEoA).

[39] Under CAIV performance and schedule are considered dependent on the funds available for a specific program. "Using affordability as the key criterion, the service headquarters divides a fixed budget among competing programs. Here the cost goals are used in developing budget required for that program and compared with the available dollars in the Program Objective Memorandum (POM) years based on the priority level established by the service, Joint Requirements Oversight Council (JROC), and others. This fixed budget based on the priority of the program is the reality of what is available for structuring the program." (Rush 1997 p.167)

VI. Six Ways to Structure an Economic Evaluation of Alternatives (EEoA)

There are six ways that analysts and decision-makers can structure a deterministic Economic Evaluation of Alternatives (EEoA). The first, third, and fourth approaches are in the spirit of cost as an independent variable (CAIV).

It is also useful to distinguish between: i) intra-program analysis approaches (#1–#5), and ii) the inter-program analysis approach (#6). In the case of intra-program analysis, the decision-maker (DM) associated with the program is assumed to have sufficient information to select an alternative without reference to competing programs. That is not the case in inter-program analysis, which requires an explicit opportunity-cost approach. The six EEoA approaches appear in Table 1.

Table 1. Six Approaches to Structure an EEoA

I. INTRA-PROGRAM ANALYSIS

A) Build Alternatives

1. Fixed-budget Approach

2. Fixed-effectiveness Approach

3. Expansion-path Approach (Construct alternatives as Cost-output/Effectiveness Relations or Response Functions: Multi-stage Micro-economic Production Model)

B) Modify Existing Alternatives: Level the Playing Field

4. Modified-budget Approach: GOTO 1

5. Modified-effectiveness Approach: GOTO 2

II. INTER-PROGRAM ANALYSIS

6. Opportunity Cost/Benefit Approach

There are two possibilities highlighted within the Intra-program analysis approach outlined in Table 1. The first possibility is that DMs (and/or analysts) are able to construct/define/build alternatives (endogenous alternatives). The second possibility is that alternatives are already constructed/defined/built (pre-specified)

and must simply be evaluated (exogenous alternatives). This section describes each of the six EEoA approaches in some detail.[40]

An earlier quote from Hitch and McKean (1967) highlights the first two EEoA approaches: "[A] criterion in which the budget or level of effectiveness is specified has the virtue of being aboveboard" (p. 167). Beginning with the Fixed-budget Approach (#1), it is useful to recall another quote from Hitch and McKean (1967): "The test of ***maximum effectiveness for a given budget*** seems much less likely to mislead the unwary" (p. 167).

1. Fixed-budget Approach.

In his groundbreaking book *Cost Considerations in Systems Analysis*, Fisher (1971) describes the first approach to EEoA:

> In the fixed budget case, the alternatives being considered are compared on the basis of effectiveness likely to be attainable for the specified budget level" (p. 12). "The analysis attempts to determine that alternative (or feasible combination…) which is likely to produce the highest effectiveness" (p. 10).

In a footnote, Fisher (1971) adds: "the fixed budget situation is somewhat analogous to the economic theory of consumer [optimization] [...]. For a given level of income [budget/funding] the consumer is assumed to behave in such a way that he maximizes his utility" (p. 10). Drawing on these observations, the Fixed-budget Approach to the EEoA leverages Lancaster's "characteristics approach to demand theory" (1966a; 1966b; 1971; 1979). Synthesizing the work of Gorman (1980), Stigler (1945), Theil (1952), and others (that also provided the early foundations of the MCDM literature), Lancaster offers economists (and defense analysts) a familiar way to analyze the consumer's (defense decision-maker's) choice problem (i.e., to choose among alternative defense investments).

---

[40] A separate paper available upon request describes the static, deterministic, multi-stage, constrained optimization, micro-economic production (procurement auction) model that underpins the third, and most general, approach to the EEoA: the Expansion-path Approach.

In Lancaster's model, different vendors generate different bundles of characteristics evaluated by decision-makers (consumers). Lancaster's model proposes that to choose among alternative bundles of commodities (say computers), defense decision-makers maximize their utility function, which is defined over a desired set of multiple criteria, attributes, or characteristics and is subject to a budget [funding/affordability] constraint.[41] In this approach, the cost-effective alternative is the one that, for a given budget (funding/expenditure/affordability level), generates the best mix of characteristics evaluated using the decision-maker's utility function.

Cost-Effectiveness EEoA

Build Alternatives

1. Fixed Budget Approach

Maximize Effectiveness subject to Budget Constraint

(construct alternatives for given budget)

Outsourcing Opportunity:
Can we get more bang for the same bucks?

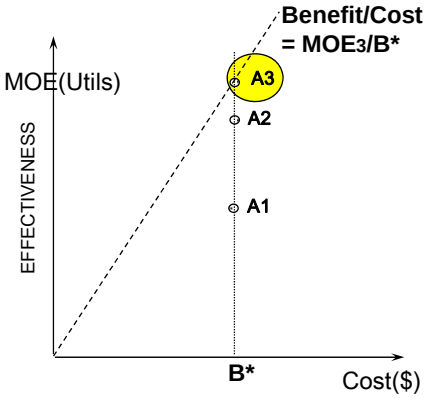


Figure 4. Fixed-budget Approach

[41] Note that we refer to the usual deterministic "utility function" that is conventional in the economics literature. This is in contrast to the way a utility function is typically defined in the decision sciences and operations management literature—that is, as a stochastic function. The value function described in the latter literature is similar to our utility function, except that costs can enter into a value function and are excluded from our utility function since they appear as part of the budget constraint.

The Fixed-budget Approach illustrated in Figure 4 is the first of six ways proposed to structure an EEoA. In Figure 4, the budget (funding/affordability level) estimate for the program is set at B*. The three vendor alternatives constructed given this budget are A1, A2, and A3. Given its superior performance in terms of its MOE, vendor A3 wins the competition, which, in this case, is also determined by the highest benefit/cost ratio.[42]

2. Fixed-effectiveness Approach

The second way to structure an EEoA is (mathematically) the dual of the first: minimize the cost of achieving a given MOE. RAND Corporation's AoA for the KC-135 Recapitalization adopts this approach: "[I]n this AoA, *the most 'cost-effective' alternative* [fleet] means precisely *the alternative whose effectiveness meets the aerial refueling requirement at the lowest cost*" (Kennedy et al., 2006, p. 7, emphasis added). Figure 5 offers an illustration in which the lowest cost option for a fixed MOE is A1, and it also offers the highest benefit/cost ratio.

Another example is provided by a section on cost-effectiveness analysis in *OMB Circular A-94* that states: "A program is cost-effective if, on the basis of life cycle cost analysis of competing alternatives, it is determined to have the lowest costs […] for a given amount of benefits [...]. Cost-effectiveness analysis can also be used to compare programs with identical costs [budgets/funding] but differing benefits" (OMB, 1992, October 29, p. 4). The latter part of the quote refers to the first approach to structuring an EEoA, and the former to the second approach.

[42] Note that in the first and second EEoA approaches, since either the budget (funding level) or MOE (level of effectiveness) is anchored in the constrained optimization, the benefit/cost ratio decision criterion can be used as a decision rule in the selection process. The steeper the slope from the origin through an alternative (A1, A2, A3), the bigger the bang-for-the-buck.

Cost-Effectiveness EEoA

Build Alternatives

2. Fixed Effectiveness Approach

Dual: Minimize Costs subject to Effectiveness Constraint

(construct alternatives for given MOE)

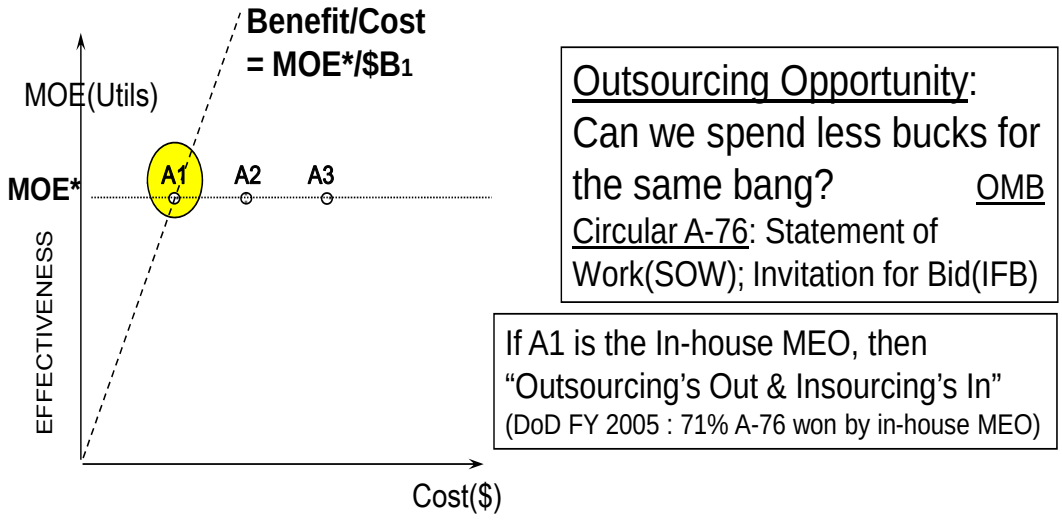


Figure 5. Fixed-effectiveness Approach

Another example of the Fixed-effectiveness Approach to structuring an EEoA is given by public-private (competitive sourcing) competitions conducted under *OMB Circular A-76*, which "requires […] a structured process for [evaluating] the most efficient and cost-effective method of performance for commercial activities" (2003, May 29, Attachment B). This involves four steps: 1) develop a Statement of Work (SOW) or Performance Work Statement (PWS) to define desired performance/effectiveness, 2) construct the Most Efficient Organization (MEO) for the in-house competitor, 3) issue an Invitation for Bid (IFB) for well-defined, routine commercial activities (SOW or PWS), and 4) compare bids or proposals (source selection) and select the "least cost" for IFB.

Finally, Title 10, Subtitle A, Part IV, Chaper 146, Section 2462 of the US Code reads:

> A function of the Department of Defense […] may not be converted […] to performance by a contractor unless the conversion is based on the results of a public-private competition that […] ***examines the cost of performance of the function by Department of Defense civilian employees and the cost of performance of the function by one or more contractors*** to demonstrate whether converting to performance by a contractor will result in savings to the Government over the life of the contract. (2007, January 3, emphasis added)

This law concerning public-private competitions offers another illustration of the Fixed-effectiveness Approach, minimizing the cost of achieving a given MOE.

3. Expansion-path (Response-function) Approach

In a quote cited above, Hitch and McKean (1967) strongly hint at the third approach to structuring an EEoA:

> The test of ***maximum effectiveness for a given budget*** seems much less likely to mislead the unwary" […]. "As a starter, […] ***several budget sizes can be assumed.*** If the same [alternative] is preferred for all […] budgets, that system is dominant. If the same [alternative] is not dominant, the use of several […] budgets is nevertheless an essential step, because it provides vital information to the decision maker. (pp. 167, 176, emphasis added)

This third way to structure an EEoA provides a foundation for all the others. It is described here, and is modeled mathematically in a companion paper (available upon request). The model involves a three-step process that includes multiple players.

For ease of exposition, we assume three players: the military buyer and two competing, private vendors. The first step is for the military buyer to issue a solicitation in the form of an Economic Request for Proposals (ERFP).

An ERFP (solicitation) states all significant non-price factors (criteria/attributes/characteristics) that the agency expects to consider in evaluating

proposals, but also includes an affordability assessment—e.g., optimistic (B1), pessimistic (B2) and most-likely budget (funding) estimates for the overall program.

Once a solicitation is issued in the form of an ERFP, interested vendors submit their offers based on the different budget scenarios (see Figure 6) and the selection process begins.[43] Each vendor responds by offering the best combination (bundle) of attributes (non-price factors) they can produce at each funding level, given their individual production and cost functions. Assuming the award is made without discussions (pursuant to *FAR* 52.212-1 and 52.215-1), the military buyer then employs a "secret" scoring rule to rank vendors.[44]

[43] The budget announcements are analogous to an agency exploring in order to uncover its true "reservation price" for the acquisition (given the competing demands for scarce budgets). The adoption of this approach of evaluating vendor proposals under different reservation prices could eventually lead to greater use of fixed-price contracts.

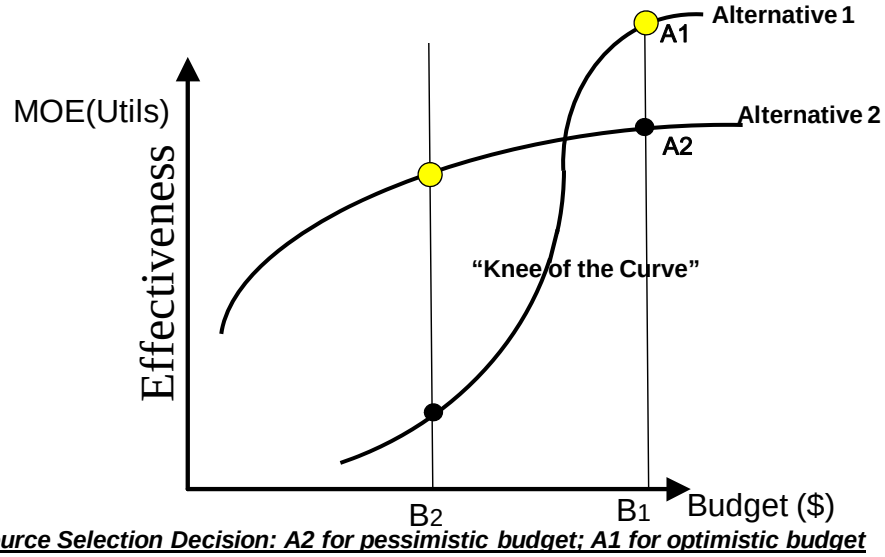
[44] The buyer reveals the desired attributes/characteristics of the investment to the sellers—but not the weights—and requests a single offer from each seller for a pre-specified budget (affordability) constraint, and then the buyer chooses the one he prefers among the submitted offers. "We call this procedure a 'single-bid auction with secret scoring rule'" (Asker & Cantillon, 2004, p. 1).

ECONOMIC APPROACH: Endogenous Alternatives ("Engel Curves")

3. Expansion Path (Response Function) Approach

(Alternatives are Cost-Effectiveness Relations, not Points)

Explore impact of budget cuts *(Identify vendor responses)*



Source Selection Decision: A2 for pessimistic budget; A1 for optimistic budget

Figure 6. Expansion path Approach

Since each vendor is assumed to have different production and cost functions to generate the desired attributes, the vendors' constrained optimizations define distinct response functions (expansion paths), one for each vendor.[45] The interesting case is where there is a crossover. For example, at the lower budget B2, Alternative 2 would be selected as offering the highest MOE, whereas with a higher budget B1 we would switch to Alternative 1. So the highest MOE attainable at each budget level is represented by the two light (yellow) points. (See Figure 6) The model is briefly described in Table 2 below.

[45] From the Envelope Theorem, the Lagrangian multiplier in each vendor's constrained optimization problem reveals the marginal product (the extra output or attribute mix they are capable of producing) as the military buyer (the DoD) relaxes or tightens its funding constraint for the overall program.

Table 2. Economic Evaluation of Alternatives (Approach #3):

Military Buyer Goal: Select an alternative that maximizes
MOE = utility function = U(non-cost factors/attributes),
Subject to BUDGET constraint

Vendor Goal: Select a mix of non-cost factors that
maximizes Q = Production Function = Q(non-cost factors/attributes)
Subject to Sum of Costs of Attributes = c1 x a1 + c2 x a2 +… < = Budget

Military Buyer Requirements
MOE: build-effectiveness model (non-cost factors: Performance = quality, schedule, etc.)
COST: build-cost model (costs/prices: Estimate total system lifecycle costs, total ownership costs)
AFFORDABILITY: Estimate budget (forecast funding available for the program: e.g. optimistic, pessimistic and most likely)

Private Vendor Requirements
Production Function: Possible attribute mixes given vendor-specific technology
Total Costs: Vendor-specific costs of producing each attribute
Vendor Proposal constructed as a function of Buyer's Budget constraint

Expansion paths exist for each vendor that reveal the combination of attributes each vendor can offer at different budget levels (e.g., pessimistic, optimistic, and most-likely).

This third fundamental EEoA approach follows our earlier quote from Hitch and McKean (1967) that recommends:

> As a starter […] several budget sizes can be assumed. If the same [alternative] is preferred for all […] budgets, that system is dominant […]. If the same [alternative] is not dominant the use of several […] budgets is nevertheless an essential step, because it provides vital information to the decision maker. (p. 176)

This is illustrated in Figure 6 with two notional budget levels: B1 (pessimistic) and B2 (optimistic). This three-stage procurement process is summarized in Table 3.

Table 3. Three-stage Multiattribute Procurement Auction (Expansion-path Approach)

1) First Stage: (CAIV)
- **The DoD provides notional budget guidance** (B) to alternative vendors for the program. The DoD searches for the optimum product (Procurement) and/or service (R&D; O&M) package that it can obtain at that price, B. The ***DoD also reveals optimistic and pessimistic budget guidance.***
- **The DoD defines the set of characteristics/attributes that it values,** and this is known to vendors. However, the DoD's precise utility function over those characteristics is unknown to vendors ("secret" scoring rule).

2) Second Stage: (Target Costing)
- **Vendors have different costs and production functions** for generating products or services (defined as bundles of characteristics).
- **Each vendor maximizes its output offer** (an optimal mix of the desired characteristics) ***subject to their particular budget constraint*** (which includes the DoD's budget guidance and the vendor's individual costs to produce a unit of each characteristic).
- **This is the product and/or service package (output) a particular vendor is able to propose for each possible budget** (B) given their production function (technical production possibilities) and their vendor-specific costs of generating those characteristics.

3) Third Stage: (Selection)
- **With the latest budget** forecast, the **DoD selects** from among the optimized characteristic bundles proposed by each ***vendor*** *the* ***bundle/alternative*** *(total product/service package)* ***that maximizes the DoD's utility function.***

In Figure 6, each vendor's expansion paths are transformed (through the government's utility function) into cost-utility or cost-effectiveness response functions (A1 and A2). These response functions reveal each vendor's proposals under different budget scenarios and represent the most general definition of "alternatives" in the Economic Evaluation of Alternatives (EEoA). Given a range of likely budgets for the program, the most effective vendor over that range of budgets can be selected by the buyer. This approach explicitly addresses a key concern voiced by the GAO:

> A cost estimate is […] usually presented to decision makers as a […] point estimate that is expected to represent the most likely cost of the program but provides no information about the range of risk and uncertainty or level of confidence associated with the estimate. (GAO, 2009, p. 9)

Suppose the planning process allows the optimistic budget assumption, B1, to be used by vendors in preparing proposals. If this is what the actual budget turns out to be, then vendor A1 would be selected. If the PPBE process ultimately narrows the budget/expenditure constraint for the program to B2, then Alternative 2 is superior. However, if vendor proposals were only solicited for the optimistic budget level, B1, then when reality strikes and budget B2 is all that is available for the program, choosing vendor proposal A1 could turn out to be a significant error (see Figure 6). This discussion reveals how the EEoA approach relies upon and reinforces the importance of iterative interactions between the requirements generation system, defense acquisition system and PPBE process.

The first three ways to structure an EEoA are for cases when alternatives can be constructed/built/designed (i.e. endogenous alternatives). The last three are appropriate when alternatives are exogenously determined (or pre-specified). The most interesting analysis in the latter case occurs when one alternative costs more but offers greater utility (MOE) and when others cost less and offer less utility (MOE).

4. Modified Budget Approach

Consider the case where alternatives are provided that have been developed exogenously—for example, on the basis of a manpower or squadron constraint (e.g., one computer per person, or a certain number of aircraft per squadron). If the overall budget or desired level of effectiveness (MOE) for a program is not available (and analysts and DMs have not structured the problem in terms of affordability), then it is likely these pre-specified alternatives solicited from different vendors have different costs and yield different measures of effectiveness (MOE). The first step in

evaluating these alternatives might be to create a scatter plot of the effectiveness and cost of the different alternatives (A1 and A2 in Figure 7).

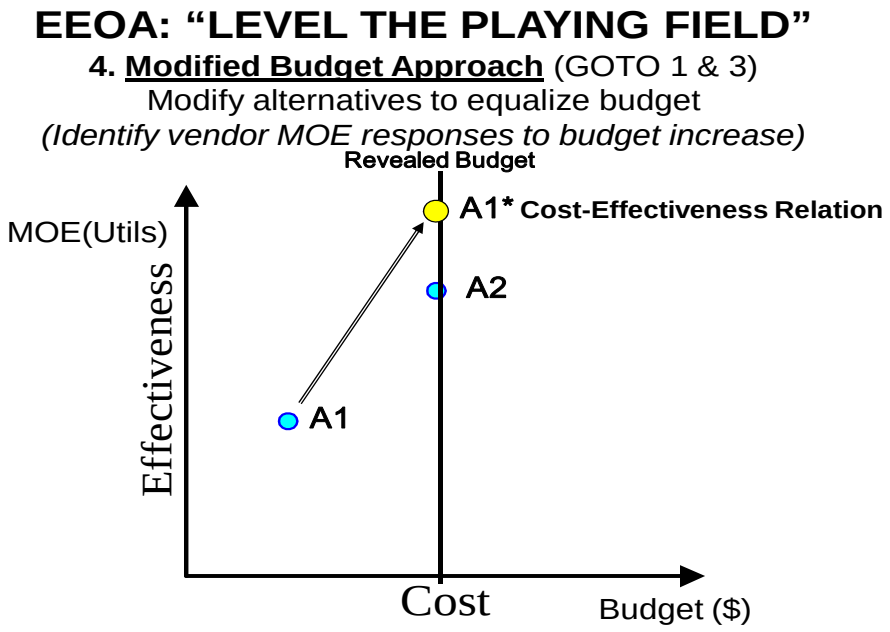


Figure 7. Modified-budget Approach

In the absence of any other information—and given two alternatives A1 and A2 that differ in both costs and effectiveness, one strategy for selecting a vendor is to level the playing field. The Modified-budget Approach asks the DM to determine the highest-cost alternative they are willing to consider (say A2), which they then use as a notional budget for the program. The fourth way to structure an EEoA recognizes that the highest-cost (highest-utility) alternative under consideration (A2 in Figure 7) reveals a possible budget constraint.

Then, in order to "level the playing field," the DM can ask the lower-cost, lower-utility vendor (that offered A1) how they might use the extra budget available to boost the utility (MOE) of their proposal. Figure 7 indicates the response from Vendor 1 is that with the same budget as Vendor 2 they are able to boost their offer

from A1 to A1*.[46] Having leveled the playing field, Vendor 1 becomes the clear winner (i.e., since for the same budget, offer A1* has a higher MOE than offer A2). Note that this approach effectively returns the problem to the first (and third) way of structuring an EEoA: maximizing effectiveness (MOE) for a given budget.

5. Modified-effectiveness Approach

Similarly, the fifth way to structure an EEoA levels the playing field for a threshold choice of utility (MOE). This returns the problem to the second (and third) way of structuring an EEoA: minimizing the cost of achieving a given level of MOE.

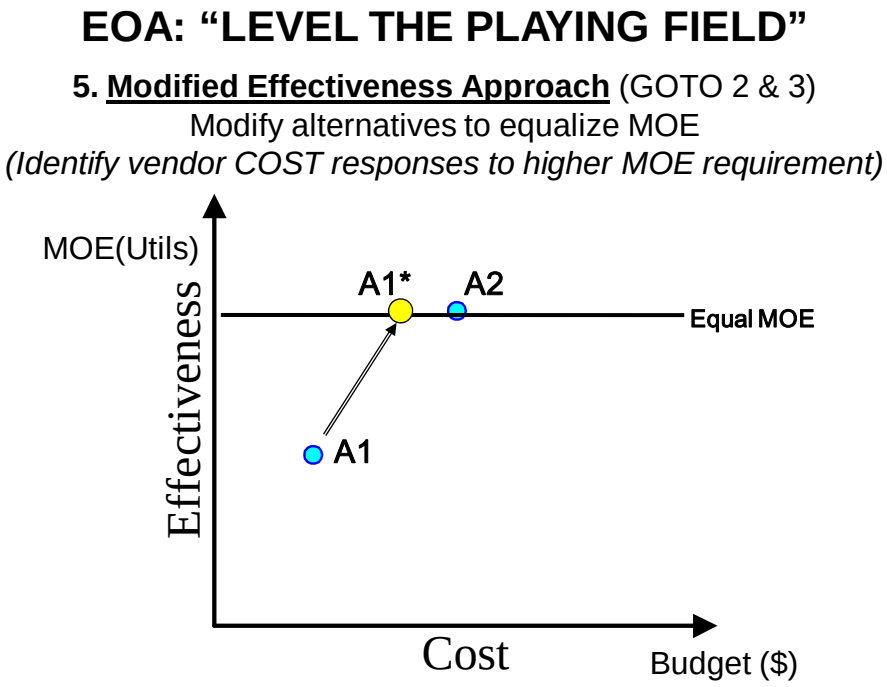


Figure 8. Modified-effectiveness Approach

[46] Alternatively, different valuable uses for the money saved by choosing the lower-cost alternative could be brought into the effectiveness calculation. Some will recognize this search for the "next best alternative use of funds" as the standard economic definition of opportunity costs. This sets the stage for the sixth way to structure an EEoA.

For example, Figure 8 shows that by anchoring the desired MOE at a target level—such as that offered by Vendor 2—the government could ask Vendor 1 how much it would cost to achieve the same target level of MOE. In Figure 8, Vendor 1 is preferred, since the response (A1*) minimizes the budget required.[47]

[47] Note that the response function for Vendor A includes points A1 and A1*.

6. Opportunity-cost (or Effectiveness) Approach

Finally, what if analysts and/or DMs find themselves in a situation in which i) alternatives cannot be modified to obtain response functions, and ii) future funding is unknown, and the desired level of MOE cannot be determined? In this case, it is likely some alternatives cost more but offer more effectiveness, while others cost less and offer less effectiveness. For example, see Program A in Figure 9.

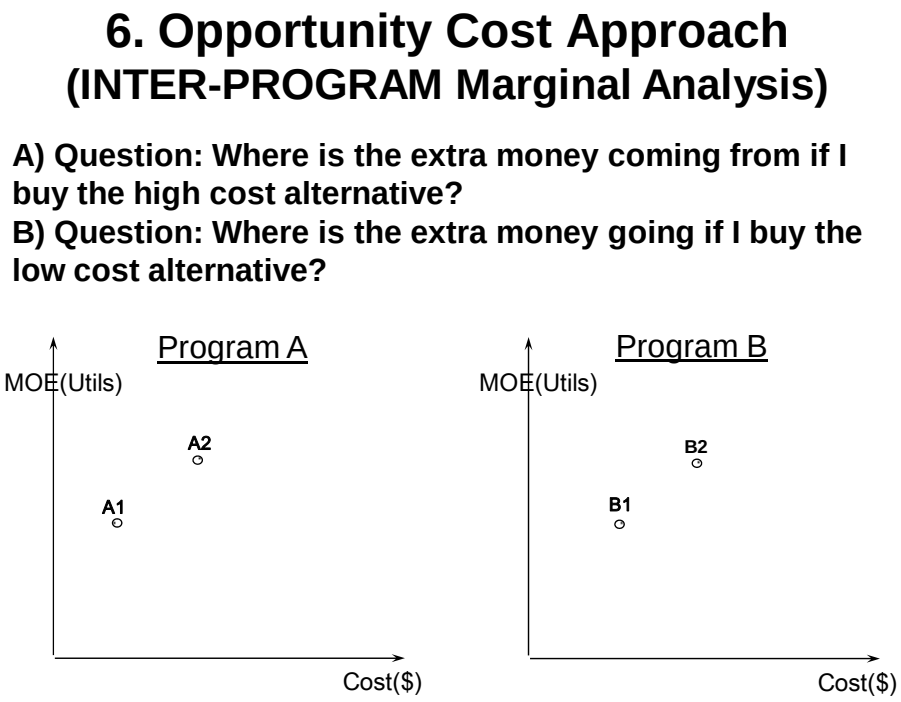


Figure 9. Opportunity-cost Approach

The sixth and final approach to structuring an EEoA involves an inter-program comparison called the Opportunity-cost Approach. Rather than modify the alternatives to level the playing field as in the EEoA approaches #4 and #5, the Opportunity-cost Approach requires a more challenging inter-program analysis to choose between lower-cost, lower-effectiveness alternatives (such as A1 in Figure 9) and higher-cost, higher-effectiveness alternatives (A2 in Figure 9). The main challenge in selecting an alternative in this context is that the DM must reach beyond the immediate program (A), into higher-level, inter-program considerations. If

alternatives are exogenously determined, and it is not possible to level the playing field, then to find the most cost-effective solution requires information about other competing programs (i.e., Program B in Figure 9).

This involves a higher-level, inter-program analysis similar to that illustrated in Figure 9. The DM must consider the loss in utility (MOE) in other programs that might be sacrificed (e.g., a budget cut in Program B, shifting the decision from B2=>B1) for funds to be released to purchase greater utility (MOE) in the program under review (e.g., a boost in the budget of Program A, shifting the decision from A1=>A2). "[T]he assessment should provide details as to how excess funding […] demands will be accommodated by reductions in other mission areas, or in other […] accounts" (DoD, 2006, July 7, Section 3.2.2).

Alternatively, DMs can explore how much more utility (MOE) the extra money might generate somewhere else if they choose the low-cost alternative (A1 in Program A). These are tough but useful questions that break through the sub-optimization of most traditional AoAs. As a consequence, the EEoA encourages critical communication to take place between different layers of the organization and a seamless interface between the Requirements Generation System, the acquisition system, and PPBS.[48]

The bottom line is that it is often more transparent, efficient, and effective to develop MOEs that are independent of costs and to treat costs as an independent variable (CAIV). Equally important are the roles of budget (funding) forecasts and

---

[48] Fisher (1965) quotes Secretary of Defense Robert McNamara: "Suppose we have two tactical aircraft which are identical in every important measure of performance [MOE] except one—aircraft A can fly ten miles per hour faster than Aircraft B. Thus, if we need about 1,000 aircraft, the total additional cost would be $10million. If we approach this problem from the viewpoint of a given amount of resources, the additional combat effectiveness…of Aircraft A would have to be weighed against the additional combat effectiveness which the same $10million could produce if applied to other defense purposes—more Aircraft B, mor or better aircraft munitions, or more ships, or even more military family housing…This kind of determination is the heart of the planning-programming-budgeting…problem with the Defense Department" (p. 182).

opportunity costs in helping structure defense investment decisions. By structuring an Economic Evaluation of Alternatives (EEoA) using one of the six approaches summarized in Figure 10, decision-makers can help achieve the primary goal of defense acquisition reform: to coordinate Requirements Generation, Defense Acquisition, and PPBS to lower costs and improve performance and schedules.

THIS PAGE INTENTIONALLY LEFT BLANK

VII. Conclusion

A. A Decision Map for Decision-makers

Given future public-spending challenges, the affordability of defense investments is a growing concern. As a consequence, it is imperative that the U.S. Department of Defense (DoD) obtain the best value for every dollar it invests in its Major Defense Acquisition Programs (MDAPs) and Major Automated Information Systems (MAISs). The primary goal of this study is to improve defense procurement decisions by bringing the taxpayer up-front alongside the warfighter in the defense acquisition process.

This study identifies several major challenges that face senior defense officials as they attempt to select the best vendor for an MDAP or MAIS through a type of military cost-benefit analysis called an "Analysis of Alternatives" (AoA). The study reveals a significant weakness in the Multiple-criteria Decision-making (MCDM) approach that underpins many contemporary AoAs. The weakness is that while MCDM techniques, and therefore most AoAs, correctly focus on lifecycle costs and the operational effectiveness of individual alternatives, affordability is often an after-thought—only implicitly addressed through a weight assigned to costs.

In sharp contrast, the Economic Evaluation of Alternatives (EEoA) introduced in this study offers a set of approaches that encourage analysts and decision-makers to embed affordability assessments directly into AoAs. This requires working with vendors to build alternatives based on different funding (budget/affordability) scenarios. Supported by a static, deterministic, constrained-optimization, micro-economic (multi-stage procurement auction) model, this EEoA approach explicitly addresses affordability up-front.[49]

[49] This study examines two popular decision criteria used by the military to structure acquisition decisions: i) benefit/cost ratios, and ii) the weighted average of benefits and costs. In the first case, the study cautions that

The key difference between the MCDM approach to AoAs and the EEoA approach is that instead of modeling decision alternatives from competing vendors as points in cost-effectiveness space, the EEoA models alternatives as functions of optimistic, pessimistic and most-likely funding (resource or budget) scenarios. In demonstrating how to embed affordability directly into an AoA, the EEoA represents an important step in the long-running effort to achieve a significant defense acquisition reform: to tightly integrate the Requirements Generation System and the Defense Acquisition System with the Planning, Programming and Budgeting System (PPBS).

The primary goal of this study was to help improve public investment decisions. An important secondary goal was to develop a Decision Map to help structure the Economic Evaluation of Alternatives (EEoA) to improve defense acquisition outcomes. This paper provides a set of six approaches that practitioners and acquisition officials can employ to structure an EEoA. The Decision Map illustrated in Figure 10 below offers a guide for senior analysts and decision-makers to select which of the six EEoA approaches is best suited to their circumstances.

In conclusion, this study offers a comprehensive set of approaches for procurement officials to structure public investment decisions. Designed to improve acquisition outcomes, the "Economic Evaluation of Alternatives" (EEoA) addresses a significant weakness in most contemporary military applications of the current methodology—the Analysis of Alternatives (AoAs). While AoAs correctly focus on

---

it is only appropriate to use benefit/cost ratios to rank alternatives when there is an explicit cost (funding/budget) constraint (or effectiveness constraint/threshold). In the second case, this study advises defining alternative funding/budget scenarios in advance to avoid the controversial task of assigning a relative weight to the cost/price of an alternative. Intuitively, if any weight whatsoever is assigned to cost, then this must imply that there is an overall funding constraint (so that costs matter), or equivalently, that there is some opportunity cost of spending money to pay for the cost/price of an alternative. This study suggests going to the source of the problem, either by identifying the likely overall budget/funding constraint for the military program, or by identifying likely alternative uses of the funds. This approach is termed the Economic Evaluation of Alternatives (EEoA).

lifecycle costs and the operational effectiveness of alternatives, “affordability” is an after-thought—at best only implicitly addressed as a weight placed on cost in the final stages of the analysis. In sharp contrast, the EEoA encourages senior analysts and decision-makers to include affordability explicitly and up-front in structuring an AoA. This requires working with vendors to build alternatives based on a reasonable spectrum of possible funding (budget or affordability) scenarios. The Decision Map below provides a comprehensive guide to EEoA for practitioners. Finally, this study demonstrates how, by embedding affordability directly into an AoA, the EEoA approach provides a unique opportunity for senior leadership to achieve a significant defense acquisition reform—to integrate Requirements Generation and Defense Acquisition with PPBS, to reduce future costs and improve performance and schedules.

Decision Map to Structure an Economic Evaluation of Alternatives (EEoA)

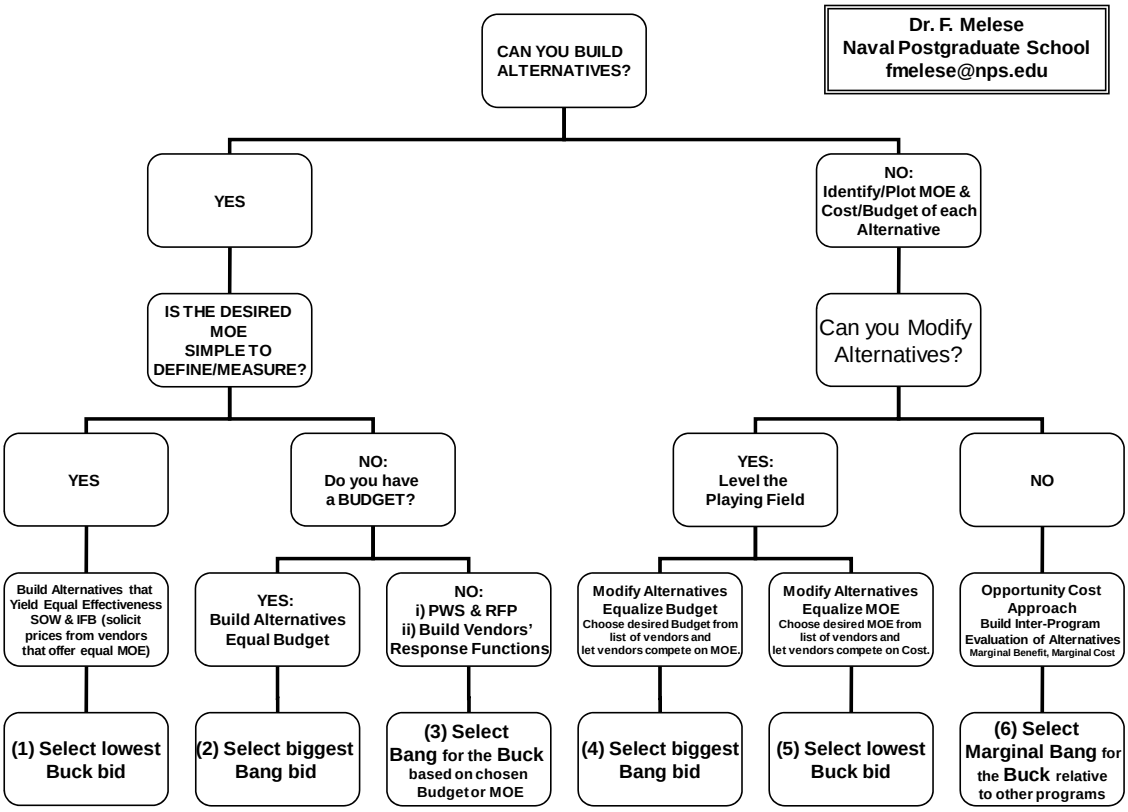


Figure 10. Decision Map to Structure an EEoA

List of References

Asker, J., & Cantillon, E. (2004). *Equilibrium in scoring auctions*. The Fondazione Enrico Mattei Note di Lavoro Series. Working Paper 2004.148.

Beil, D., & Wein, L. (2003). An inverse-optimization-based auction mechanism to support a multiattribute RFQ process. *Management Science*, *49*(11), 1529-1545.

Business Executives for National Security (BENS). (2009, July). Getting to best: Reforming the defense acquisition enterprise. *BENS Executive Summary*.

Byrns, E., Corban, E., & Ingalls, S. (1995, Winter). A novel cost-benefit analysis for evaluation of complex military systems. *Acquisition Review Quarterly*.

Chairman of the Joint Chiefs of Staff (CJCS). (2007, May). *Joint capabilities integration and development system (JCIDS)* (CJCS Instruction J-8 CJCSI 3170.01F). Washington, DC: Author.

Chairman of the Joint Chiefs of Staff (CJCS). (2009, March 1). *Joint capabilities integration and development system (JCIDS)* (CJCS Instruction 3170.01G). Washington, DC: Author.

Che, Y. (1993). Design competition through multidimensional auctions. *RAND Journal of Economics*, *24(4) pp668-680*.

Clemen, R. (1996). *Making hard decisions: An introduction to decision analysis* (2nd ed.). Belmont, CA: Duxbury Press.

Corner, J., & Kirkwood, C. (1991). Decision analysis applications in the operations research literature. *Operations Research*, *39*(2)*, pp206-219*..

Davis, P. (2002). *Analytic architecture for capabilities-based planning, mission-system analysis, and transformation*. Santa Monica, CA: National Defense Research Institute, RAND.

DoA. (1999, July 15). *Army acquisition procedures* (Pamphlet 70-3). Washington, DC: US Army Headquarters.

DoA. (2001, February). *Economic analysis manual.* Arlington, VA: US Army Cost and Economic Analysis Center.

DoD. (1984, May 22). *The planning, programming, and budgeting system (PPBS)* (DoD Directive 7045.14). Washington, DC: Author.

DoD. (1987, April 9). *Implementation of the planning, programming, and budgeting system (PPBS)* (DoD Directive 7045.07). Washington, DC: Author.

DoD. (1995, November 7). *Economic analysis for decision making* (DoD Directive 7041.3). Washington, DC: Author.

DoD. (1998). *DoD guide to cost as an independent variable* (DA PAM 70-3). Washington, DC: Author.

DoD. (2006, July 7). *Defense acquisition guidebook* (Ver. 1.6). Chapter 1.1 (Integration of the DoD Decision Support System); Chapter 1.2 (Planning, Programming, Budgeting and Execution Process; Office of Management and Budget (OMB) and the PPBE Process). Retrieved March 16, 2009, from https://acc.dau.mil

DoD. (2008, January 10). *Defense federal acquisition regulation supplement (DFARS)*. Washington, DC: Author.

Dyer, S., & Sarin, R. (1979). Measurable multi-attribute value functions. *Operations Research, 27(4) p810.*

Dyer, S., Fishburn, P., Steuer, R., Wallenius, J., & Zionts, S. (1992). Multiple criteria decision making, multi-attribute utility theory. *Management Science*, *38*(5)*, pp645-654*.

Edwards, W., von Winterfeldt, D., & Moody, D. (1988). Simplicity in decision analysis. In D. Bell, H. Raiffa, & A. Tversky (Eds.), *Decision making: Descriptive, normative, and prescriptive interactions* (pp. 443-464). Cambridge, UK: Cambridge University Press.

Eger, R., & Wilsker, A. (2007). Cost effectiveness analysis and transportation: Practices, problems and proposals. *Public Budgeting and Finance*, *27*(1) *pp104-116*.

European Commission (EC). (2004a). *Coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors* (EC Directive 2004/17/EC of the European Parliament and of the Council of 31 March 2004), Article 55 of the European Commission.

European Commission (EC). (2004b). *On the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts* (EC Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004), Article 53 and 54 of the European Commission.

Ewing, P., Tarantino, W., & Parnell, G. (2006). Use of decision analysis in the Army base realignment and closure (BRAC) 2005 military value analysis. *Decision Analysis*, *3*(1)*,pp33-49*.

Fisher, G. (1965). The role of cost-utility analysis in program budgeting. In D. Novick (Ed.), *Program budgeting*. Cambridge, MA: Harvard University Press.

Fisher, G. (1971). *Cost considerations in systems analysis.* New York: American Elsevier Publishing.

Fowler, B., & Cason, P. (1998). The cost exchange ratio: A new aggregate measure of cost and operational effectiveness. *Journal of the Military Operations Research Society*, *3*(4),*pp57-64*.

French, S. (1986). *Decision theory: An introduction to the mathematics of rationality*. Cambridge: Ellis Horwood.

Gansler, J. (2003, June). *Moving toward market-based government*. New Ways to Manage Series. Washington, DC: IBM Endowment for the Business of Government.

GAO. (2008, July 2). *Defense acquisitions: A knowledge-based funding approach could improve major weapon system program outcomes* (GAO-08-619). Washington, DC: Author.

GAO. (2008, September 25). *Defense acquisitions: Fundamental changes are needed to improve weapon program outcomes* (GAO-08-1159T). Testimony of M. Sullivan, Director of Acquisition and Sourcing Management before the Subcommittee on Federal Financial Management, US Senate. Washington, DC.

GAO. (2008, December). *Defense logistics: Improved analysis and cost data needed to evaluate the cost-effectiveness of performance-based logistics* (GAO-09-41). Washington, DC: Author.

GAO. (2009, March 18). *Defense acquisitions: DoD must prioritize its weapon system acquisition and balance them with available resources* (GAO-09-501T). Testimony of M. Sullivan, Director of Acquisition and Sourcing Management before the Committee on the Budget, House of Representatives. Washington, DC.

GAO. (2010, January 20). *Defense acquisitions: Managing Risk to achieve better outcomes* (GAO-10-374T). Testimony of P. Francis, M. Golden & W. Woods before the Subcommittee on Defense, Committee on Appropriations, House of Representatives. Washington, DC.

General Services Administration, Department of Defense, National Aeronautics and Space Administration. (2005, March). *Federal acquisition regulation (FAR)*. Washington, DC: Author.

Golabi, K., Kirkwood, C., & Sicherman, A. (1988). Selecting a portfolio of solar energy projects using multiattribute preference theory. *Management Science, 27(2) pp174-189*.

Gorman, W. (1980). The demand for related goods: A possible procedure for analysing quality differentials in the egg market. *Review of Economic Studies, 47(150) pp843-856*.

Henry, M., & Hogan, W. (1993). Cost and effectiveness integration. *PHALANX,* .

Hitch, C., & McKean, R. (1967). *The economics of defense in the nuclear age*. Cambridge, MA: Harvard University Press.

Howard, R. (1988). Decision analysis: Practice and promise. *Management Science, 34(6) pp679-695*.

Hwang, C., & Yoon, K. (1981). *Multiple-attribute decision making: Methods and applications.* New York: Springer-Verlag.

Keeney, R. (1982). Decision analysis: An overview. *Operations Research, 30*(5) pp803-838.

Keeney, R. (1992). *Value-focused thinking.* Cambridge, MA: Harvard University Press.

Keeney, R. (1994). Using values in operations research. *Operations Research, 42*(5)*,pp793-813*.

Keeney, R., & Raiffa, H. (1976). *Decisions with multiple objectives: Preferences and value tradeoffs*. New York: John Wiley & Sons.

Kennedy, M., Baldwin, L., Boito, M., Calef, K., Chow, J., Cornuet, J. et al. (2006). *Analysis of alternatives (AoA) for KC-135 recapitalization.* Santa Monica, CA: Project Air Force, RAND.

Kirkwood, C. (1997). *Strategic decision making.* New York: Duxbury Press.

Lancaster, K. (1966a). A new approach to consumer theory. *Journal of Political Economy*, *74(2) pp132-197*.

Lancaster, K. (1966b). Change and innovation in the technology of consumption. *American Economic Review*, 56(2) pp14-23.

Lancaster, K. (1971). *Consumer demand: A new approach*. New York: Columbia University Press.

Lancaster, K. (1979). *Variety, equity, and efficiency*. New York: Columbia University Press.

Larsen, R., & Buede, D. (2002). Theoretical framework for the continuous early validation method. *Systems Engineering*, *5*(3)*,* #-#.

Liberatore, M. (1987). An extension of the analytic hierarchy process for industrial R&D project selection and resource allocation. *IEEE Transaction on Engineering Management*, *34*(1)*,pp12-108*.

Lorell, M., & Graser, J. (2001). *An overview of acquisition reform cost saving estimates*. Santa Monica, CA: Project Air Force, RAND.

Melese, F., Angelis, D., Coughlan, P., Kidalov, M., Gates, W., Franck, R., & CJ LaCivita, (2010, Jan 31). A New Paradigm to Address Bid Protests, USAF Technical Report, Monterey, CA: Naval Postgraduate School.

Melese, F. (2007, May 17). Outsourcing for optimal results: Six ways to structure an analysis of alternatives. In *Proceedings of the 4th Annual Acquisition Research Symposium* (Creating Synergy for Informed Change). Monterey, CA: Naval Postgraduate School.

Melese, F., & Bonsper, D. (1996, December). Cost integration and normalization issues. *PHALANX*, *29*(4)*,* #-#.

Melese, F., Franck, R., Angelis, D., & Dillard, J. (2007, January). Applying insights from transaction cost economics to improve cost estimates for public sector purchases: The case of U.S. military acquisition. *International Public Management Journal*, *10(*4)*,pp357-385*.

Melese, F., Stroup, M., & Lowe, J. (1997). Integrating cost and effectiveness: An economic perspective. *PHALANX*, *30*(3)*,* #-#.

Michael, R., & Becker, G. (1973). On the new theory of consumer behavior. *Swedish Journal of Economics*, *75*(4) pp378-396.

Murray, C. (2002). *Executive decision making* (6th ed.). Newport, RI: National Security Decision Making Department, US Naval War College.

Newell, E. (2009, July 27). Business group urges reform of Pentagon contract requirements process. *Government Executive.* Retrieved December 2009, from http://www.govexec.com

OMB. (1976, April 5). *Major systems acquisitions* (OMB Circular A-109). Washington, DC: Author.

OMB. (1992, October 29). *Guidelines and discount rates for benefit-cost analysis of federal programs* (OMB Circular A-94). Washington, DC: Author.

OMB. (2003, May 29). *Performance of commercial activities (public-private competitions)* (OMB Circular A-76 (Revised)). Washington, DC: Author.

Parkes, D., & Kalagnanam, J. (2005). Models for iterative multiattribute procurement auctions. *Management Science*, *51*(3)*,pp435-451*.

Parnell, G. (2006). Value-focused thinking using multiple objective decision analysis. In *Methods for conducting military operational analysis* (Chap. 19). Alexandria, VA: Military Operations Research Society.

Pinker, A., Samuel, A.H., & Batcher, R. (1995, December). *On measures of effectiveness*. *PHALANX, vol*(issue), #-#.

Quade, E. (1989). *Analysis for public decisions* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Ramesh, R., & Zionts, S. (1997). Multiple criteria decision making. In S. Gass & C. Harris (Eds.), *Encyclopedia of Operations Research and Management Science* (pp. 538-543). Boston, MA: Kluwer.

Retchless, T., Golden, B., & Wasil, E. (2007). Ranking US Army Generals of the 20th century: A group decision-making application of the analytic hierarchy process. *Interfaces*, *37*(2)*,pp163-175*.

Ruefli, T. (1971). PPBS—An analytical approach. In R. Byrne et.al. (Eds.), *Studies in budgeting* (pp. #-#). Amsterdam: North Holland.

Ruefli, T. (1974). Analytic models of resource allocation in hierarchical multi-level systems. *Socio-Economics Planning Science*, *8,* #-#.

Rush, B. (1997). Cost as an independent variable: concepts and risks. *Acquisition Review Quarterly*, Spring

Saaty, T. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, *15(3) pp234-281*.

Saaty, T. (1980). *The analytic hierarchy process.* New York: McGraw-Hill.

Smith, J., & von Winterfeldt, D. (2004). Decision analysis in management science. *Management Science*, *50*(5)*,pp561-574*.

Station. (1956, November).

Stigler, G. (1945). The cost of subsistence. *Journal of Farm Economics*, *27,pp303-314*.

Theil, H. (1952). Qualities, prices and budget enquiries. *Review of Economic Studies*, *19(3) pp129-147*.

Thomas, C., & Sheldon, R. (1999). The knee of the curve. *Military Operations Research*, *4*(2)*, #-#*.

Under Secretary of Defense (AT&L). (2007, November 20). *The defense acquisition system* (DoD Directive 5000.01). Washington, DC: Author.

Under Secretary of Defense (AT&L). (2008, December 8). *Operation of the defense acquisition system* (DoD Instruction 5000.02). Washington, DC: Author.

US Code. (2007, January 3). Title 10, Chapter 146, Sec. 2462, Subtitle A, Part IV. Washington, DC: US Government Printing Office.

US Congress. (1994). *Federal acquisition streamlining act of 1994* (Public Law 103-355). 103rd Congress, 2nd Session. Washington, DC: US Government Printing Office.

US Congress. (1995). *Federal acquisition reform act of 1995* (Public Law 104-106). Washington, DC: US Government Printing Office.

US Congress. (1996). *Information technology management reform act of 1996* (Public Law 104-106). Clinger-Cohen act. Washington, DC: US Government Printing Office.

US Congress. (1997, February 10). 104th Congress, 2nd Session. Washington, DC: Chief Information Officers Council.

US Congress. (1998). *Federal activities inventory reform act of 1998* (Public Law 105-270). Washington, DC: US Government Printing Office.

Vazsonyi, A. (1995, December/January). Multicriteria decision making. *Decision Line*, *26*(1)*, #-#*.

Willard, D. (1998). Cost-effectiveness, CAIV, and the knee of the curve. *PHALANX*, *31*(3)*, #-#*.

Winterfeldt, D., & Edwards, W. (1986). *Decision analysis and behavioral research*. Cambridge, UK: Cambridge University Press.

Zahedi, F. (1986). The analytic hierarchy process—A survey of the method and its applications. *Interfaces*, *16(4) pp96-108*.

Zionts, S. (1980). Methods for solving management problems involving multiple objectives. In G. Fandal & T. Gaul (Eds.), *MCDM: Theory and applications* (pp. #-#). New York: Springer-Verlag

Appendix 1. Mathematical Appendix

(Available upon Request)

THIS PAGE INTENTIONALLY LEFT BLANK

2003 - 2009 Sponsored Research Topics

Acquisition Management

- Acquiring Combat Capability via Public-Private Partnerships (PPPs)
- BCA: Contractor vs. Organic Growth
- Defense Industry Consolidation
- EU-US Defense Industrial Relationships
- Knowledge Value Added (KVA) + Real Options (RO) Applied to Shipyard Planning Processes
- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-tem Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

A complete listing and electronic copies of published research are available on our website: www.acquisitionresearch.org

THIS PAGE INTENTIONALLY LEFT BLANK

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CALIFORNIA 93943

www.acquisitionresearch.org