

Analysis of Alternatives (AoA) Based Decisions

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MORS, Phalanx, Vol 44, No 3, Sept 2011, pp 24

The Analysis of Alternatives (AoA) is a process that has been adopted by the Office of Management and Budget (OMB) and the Department of Defense (DoD) to ensure that multiple alternatives have been analyzed prior to making investment decisions. It is an assessment approach to evaluate potential solution sets (material, organizational, structural, or ideological) to satisfy a desired capability. An AoA moves the justification of a single alternative to the exploration of multiple options in order to establish a basis for funding the best possible projects in a rational, defensible manner while considering risk and uncertainty. As with other decision-making tools, techniques, and procedures, a mature AoA is best used in a higher-level decision-making context.

What Is AoA? Why Conduct Them?

Analysis of Alternatives is the detailed analytical comparison of multiple options before committing resources to an objective or goal. The practice of comparing multiple alternative solutions has long been a part of engineering practice (Ullman, 2009, especially Chapter 7, Concept Generation). However, there is a natural tendency to pre-select a single alternative and justify it rather than compare multiple options with the goal of choosing the best one. Justification appears easier than evaluation when making a learned decision. Thus, government agencies, such as OMB and DoD, have made it necessary to require the use of a rigorous AoA process when proposing program solutions.

To facilitate this AoA introduction, there are 4 levels of AoA maturity:

- Level 1 – Propose one alternative and justify it.
- Level 2 – Propose multiple alternatives and provide a one-dimensional comparative analysis with some inclusion of uncertainty effects.
- Level 3 – Propose multiple alternatives and provide multi-dimensional comparative analysis with some inclusion of uncertainty effects.
- Level 4 – Propose multiple alternatives, and provide multi-dimensional comparative analysis and support robust resource allocation decisions with the inclusion of uncertainty effects.

These levels include measures about the number of alternatives considered, the inclusion of uncertainty in the analysis, and the level of decision support. Additional levels could be defined by considering these measures separately, but these four levels are sufficient for the processes used today.

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This paper will show how OMB provides funding approval from Level 1 to Level 2, and how DoD sets a goal to achieve Level 3 AoA. Further, the paper will show that current AoA methods only go part of the way to achieving the highest potential – Level 4 AoA. Keep in mind that the ultimate goal of an AoA exercise is to enable making the best possible decision about resource allocations where this decision is based on uncertain, incomplete, evolving, and conflicting estimates of cost, performance, and other critical measures. In this paper, the OMB and DoD approaches to AoA are discussed first, and then AoA’s potential will be explored.

The Value of an AoA Depends on Estimation and Risk

The “analysis” in AoA refers to making estimates of future costs, delivery schedule, performance and other critical measures in order to understand the risk of following a course of action. As Chapter 3 in *Making Robust Decisions* (Ullman, 2006) points out about estimates, “Where the past performance may be known, the present is obscured by its immediacy and the future is a best guess.” The best guess is clouded in uncertainty and uncertainty results in risk. Uncertainty comes from many sources², and these can be characterized by the types of resulting risks: technical risks, programmatic risks, operational risks and decision risks. The first three are typically part of every AoA; but the last one, decision risk, the risk of choosing the wrong alternative when performing an AoA, is often omitted and needs to be known.

Time, cost, and performance estimations are notoriously inaccurate. In one government agency, cost overruns range from 31% (small projects) to 315% (very large projects)³. As another example of estimation inaccuracy, in the *Chaos Report* (Standish Group, 2000 and 2004) an annual analysis of information technology (IT) projects, 51% of all IT projects were delivered late or over budget in 2004 and an additional 15% were cancelled. Further, projects completed by large companies had only 42% of the originally designed features and functions. It should be noted that the *Chaos Report* numbers may actually be understated, as they are self-reported.

In a simple estimation exercise described in *Making Robust Decisions*, time estimates were made for a basic, everyday task by hundreds of attendees at a conference. The resulting estimates averaged 32 minutes with a standard deviation of 10 minutes. In other words over 30% of the estimates were more than 10 minutes more or less than the average. Further, by simply changing the wording of the estimate request, the average estimate dropped to 17 minutes. In other words, by asking a single estimator for the time required to do a task, even a common one, will result in an estimate that is not much better than a guess.

Risk is due to uncertainty - without any uncertainty, reality will match the estimate and the risk will be zero. Formally, risk is the likelihood of something going wrong times the consequences if it does. The goal of including uncertainty in AoA is to help analyze risk. In terms of the estimation exercise example in the previous paragraph, it should be

² Eleven specific sources are cited in *Making Robust Decisions*. Ullman 2006.

³ Will need to specify source.

possible in an AoA to include the uncertainty of time estimates as they may have a marked impact on cost and material maturity when it comes to making decisions.

The Office of Management and Budget AoA Effort

Part 7 (Section 300) of the OMB Circular A-11 (OMB, 2008) establishes a policy for planning, budgeting, acquisition, and managing Federal capital assets, and gives instructions on budget justification and reporting requirements. This is an effort to move organizations from justifying a single alternative, Level 1 AoA, to the comparison of multiple alternatives. Within the OMB and other government agency literature, AoA is often referred to as “Alternatives Analysis.” Details on alternatives analysis is given in Appendix A of GSA’s *IT Budget Submission Instructions* (GSA, 2007).

In order to achieve Level 2 AoA, Section 300 requires that an organization identify and consider at least three viable alternatives, in addition to the current baseline (i.e., the status quo). These alternatives need to be presented in a table that shows:

- Alternative Analyzed
- Description of Alternative
- Risk Adjusted Lifecycle Costs estimate – the overall estimated cost over the life of the investment that has been adjusted to accommodate any risk identified
- Risk Adjusted Lifecycle Benefits estimate – projected benefits and costs for each viable alternative

The GSA *IT Budget Submission Instructions* goes on to say that the following quantitative and qualitative benefits should be addressed when evaluating total annual benefits for each alternative:

- Qualitative Benefits
- Cost Savings
- Cost Avoidance
- Stakeholder Benefits
- Non-Monetary Quantitative Benefits

In both the OMB and GSA documents, the comparison is based on Net Present Value (NPV), an effort to reduce all measures to their dollar values. There is great comfort in having a single dollar value for each project. But, is this value sufficient for actually committing resources? Using only NPV has the following shortcomings:

- The accuracy of the data is suspect; using a single indicator of project value only combines inaccurate estimates, thus compounding the error.
- Risk estimates are added to NPV and are often no better than an educated guess, further compounding the error.
- NPV penalizes projects with longer-term launch dates.
- NPV assumes that risk (uncertainty) is spread out evenly over the life of a project, which is often not true.

- It is difficult to measure everything in terms of dollars. Time is money, but time estimates are often inaccurate.

In concluding an AoA study for the OMB, the organization must also provide information describing the estimating technique used, why the selected alternative was chosen, and what specific qualitative benefits will be realized. The level of detail and rigor of a cost benefit analysis should be commensurate with the size, complexity, and cost of a project. Cost/benefit projections should be calculated for all viable alternatives.

To accommodate the risks in the estimates, the OMB and GSA give little guidance. The best to be found is in Section 9 of *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (OMB, 2006). Here it states that estimates of benefits and costs are typically uncertain because of imprecision in both underlying data and modeling assumptions. The guidance in the half-page of coverage is limited to “objective estimates of probabilities should be used whenever possible,” and the suggestion that any limitations of the analysis because of uncertainty should be discussed.

What should be drawn from the above discussion is that OMB forces AoA Level 1 policies to Level 2 using solely NPV. NPV is certainly one appropriate measure, but it is not the only measure that should be included in an AoA.

The Department of Defense AoA Effort

In DoD AoA is used in the decision-making process to support acquisition of new capabilities and systems. By definition, “(t)he AoA shall focus on identification and analysis of alternatives, measures of effectiveness, cost, schedule, concepts of operations, and overall risk. The AoA shall assess the critical technology elements (CTEs) associated with each proposed materiel solution, including technology maturity, integration risk, manufacturing feasibility, and, where necessary, technology maturation and demonstration needs”⁴. DoD instruction 5000.2 (2008) provides AoA procedural guidance for potentially high cost projects referred to as Acquisition Category I (ACAT 1 or 1A) programs. The procedure describes the requirement of the Milestone Decision Authority (MDA) to approve AoA guidance to the service lead or to the Principle Staff Assistant in charge of the mission area. Which in turn designate responsibility to complete the AoA study plan. In order to avoid conflict of interest, the program manager (PM) will not be assigned that responsibility. The AoA study plan must be approved by the MDA prior to the start of the AoA. The OSD Cost, Assessment & Program Evaluation office provides an independent assessment of the AoA to the MDA (CAPE - formally known as Program Analysis & Evaluation (PA&E)) in the following areas⁵:

- Illuminated capability advantages and disadvantages
- Considered joint operational plans
- Examined sufficient feasible alternatives

⁴ DoD Instruction 5000.2, December 8, 2008, page 15.

⁵ DoD Instruction 5000.2, December 8, 2008, page 58.

- Discussed key assumptions and variables and sensitivity to changes in these
- Calculated costs
- Assessed Technology risk and maturity, Alternative ways to improve the energy efficiency, and Appropriate system training

Although the AoA is only required by statute for the initial milestone decision, (milestone A) updates may be necessary for follow-on critical decisions (milestone B and C). Each update has renewed guidance and the need for an approved study plan. The AoA study plan describes “how’ the AoA will be conducted to include approach and methodology.

Each Service has its own AoA methodology, for example, the Army headquarters Operations (G3/5/7) issues study guidance as a formal tasking to the analytical agency of choice. Typically, the Training and Doctrine Command (TRADOC) is the lead organization. TRADOC in turn issues a tasking to a subordinate analytical center within its organization. Although the multilayered process may appear cumbersome, the detailed command structure clearly identifies an approval chain enabling the AoA to progress in the desired direction. The analytical organization responsible for the AoA uses a series of regulations and pamphlets out of the Army Headquarters and TRADOC to provide additional guidance on the conduct of AoA, but not to the level of specificity that would hamper analytical organizations from tailoring each AoA to individually assess and evaluate the potential program⁶. The Army’s TRADOC Analysis Center (TRAC) often is responsible for the conduct of ACAT 1 and II programs while the mission area leads (school houses) are responsible for less cost prohibitive programs.

Similar to the Army, the Assistant Secretary of the Navy Research, Development and Acquisition (ASN (RDA)) releases guidance on AoA preparation and a proposal is prepared in coordination with major stakeholders. The interested parties may include decision makers (program sponsor) and the program manager team. The AoA is conducted by a service provider which can be a Navy Study Center (for example, the Center for Naval Analysis (CNA)) or one of the many federally funded research and development centers (FFRDC). The Navy forms an oversight board and receive feedback of AoA development to include study plan approval that includes the methodology and approach⁷.

Perhaps the best documented AoA methodology and approach is detailed in the Air Force Materiel Command *Analysis of Alternatives (AoA) Handbook* (USAF, 2008). It is a handbook of useful analysis tools and techniques. We will use material from it in this discussion.

⁶ The primary references for the Army are Army Regulation 71-9 (AR-71-9), December 28, 2009; TRADOC Regulation 10-5-7 which describes the mission role of TRAC organizations, TRADOC Regulation 71-20 used for force development, and TRADOC Pamphlet 350-70-6 on the conduct of analysis.

⁷ Defense Acquisition University, Analysis of Alternatives, April 2006 page 4.

DoD AoA studies span two main categories of measures, effectiveness, and cost. The combination of effectiveness and cost results in a set of multiple measures; thus DoD AoA studies are at Level 3.

Cost analysis is performed similar to the methods suggested in the OMB and GSA literature. But instead of translating all measures into NPV, the DoD also considers effectiveness analysis. Measuring effectiveness is normally the most complex element of the AoA and consumes a significant fraction of AoA resources. The goal of the effectiveness analysis is to determine the military worth of the alternatives relative to qualitative or quantitative measures. These focus on a system's performance or characteristics that indicates the degree to which it performs the goal task. These measures of effectiveness (MOEs) are:

- Quantitative when feasible (e.g., "the number of targets held at risk," or "the number of targets by type that you can hold at risk in daytime and nighttime conditions")
- Qualitative when necessary, calling on the opinion of a knowledgeable person or group, (e.g., "In your opinion does the solution provide a day-night capability?")
- Universal across all the alternatives, as all alternatives are evaluated using all MOEs
- Independent – not strongly correlated with one another (to avoid overemphasizing particular aspects of the alternatives)

There is only minimal consideration of risk and uncertainty in the handbook. The section covering this topic (7.3.4) concludes with, "Several approaches are available to treat risk in an estimate; they range from very subjective to those with complex statistics. Whatever risk methodology the cost analyst decides to employ, it should be adequately described in the study plan. The results of the risk analysis will be included in the final cost estimates."

The Air Force *Handbook* clearly recognizes that the goal of an AoA study is to make a decision, but not sufficiently to be considered Level 4. The methods for alternative comparison in the handbook are paraphrased and will serve as a basis for discussion in the final part of this paper.

The *Handbook* suggests a filtering of possible alternatives to eliminate those that are not viable, cost effective, or otherwise lacking as shown in Figure 1, taken from the *Handbook*. This filtering (similar to that suggested in *The Mechanical Design Process*), is strong, but grows weak when discussing how to select among the finalists (Options 2, 6, and 7, in Figure 1).



Figure 1, Filtering of Alternatives

What is suggested is that plots of cost versus effectiveness be made to support the alternatives comparison. These can show the cost- effectiveness trade-off. The *Handbook* is never quite clear about how to combine the MOEs into a single “effectiveness,” metric or how to find uncertainty. In the discussion, the authors go on to say, in highlighted font, that *there is generally no requirement for an AoA to identify a SINGLE solution.* But if the goal is to support decision making, then guidance about how to get to a single solution may be necessary.

Once the analysis is complete, it is useful to present a summary of the key discriminators for each alternative side-by-side before presenting the conclusions and recommendations drawn from all of the analysis. Figure 2 shows an example of this sort of presentation, an alternative comparison matrix, where LCC represents Life Cycle Cost. This kind of depiction ensures that the report reader or briefing audience has a summary picture of the results in mind (and for reference) as the conclusions and recommendations are made.

	Critical									Non-Critical			Risk	Total LCC \$(M)
	Mission Task 1			Mission Task 2			Mission Task 3							
	MoE 1-1	MoE 1-2	MoE 1-3	MoE 2-1	MoE 2-2	MoE 2-3	MoE 3-1	MoE 3-2	MoE 3-3					
Alt 1 (baseline)	G	Y	R	G	G	Y/G	G	R	G	R	\$1,200			
Alt 2	R	Y/G	G	R/Y	R	G	G	Y/G	Y	G	\$1,450			
Alt 3	Y/G	G	R	G	Y	Y/G	Y	G	G	R	\$1,457			
Alt 4	G	R	G	R/Y	G	Y	R/Y	G	R	G	\$1,786			

Figure 2, Alternative Comparison Matrix

The next step in this process is to find a way to clearly identify for the decision makers the advantages and disadvantages of each alternative, especially how the alternatives address the required capabilities and answer the high-level issues/questions in the AoA guidance.

Where the DoD approach to AoA is more mature than that of OMB, it could still improve in two areas: handling of uncertainty and a decision centric approach to the problem.

Taking the AoA to the Next Level

As stated in the introduction, the ultimate goal of AoA is to support making resource allocation decisions. Where OMB pushes Federal agencies to Level 2 AoA and the DoD manages Level 3, neither meets the qualifications for Level 4. In this section we will explore what it will take to meet the stated definition:

Level 4 – Propose multiple alternatives, and provide multi-dimensional comparative analysis and support robust resource allocation decisions with the inclusion of uncertainty effects.

This definition has the following constituent parts:

- A decision process approach
- Multi-dimensional qualitative and quantitative comparisons
- An integration of estimation uncertainty
- The ability to fuse evaluations to give guidance to the process

Of these, the second part is developed in the USAF AoA *Handbook* and the third and fourth parts are recognized but could use additional support. The following describes what is needed to fulfill all these AoA needs.

At times, it may seem that the conduct of an AoA is a requirement to do analysis for the sake of analysis - unless the final goal is kept in sight: from a set of alternatives, choose the one most likely to be successful or identify what needs to be done next to make this decision. Thus, an AoA should center on the elements of a decision process. As shown in Figure 3, there are four main activities necessary for information generation and refinement during the decision-making process: understand, evaluate, fuse, and decide. Note that the decision to choose an alternative – the last item in “what-to-do-next” – is only one activity of the decision-making process.

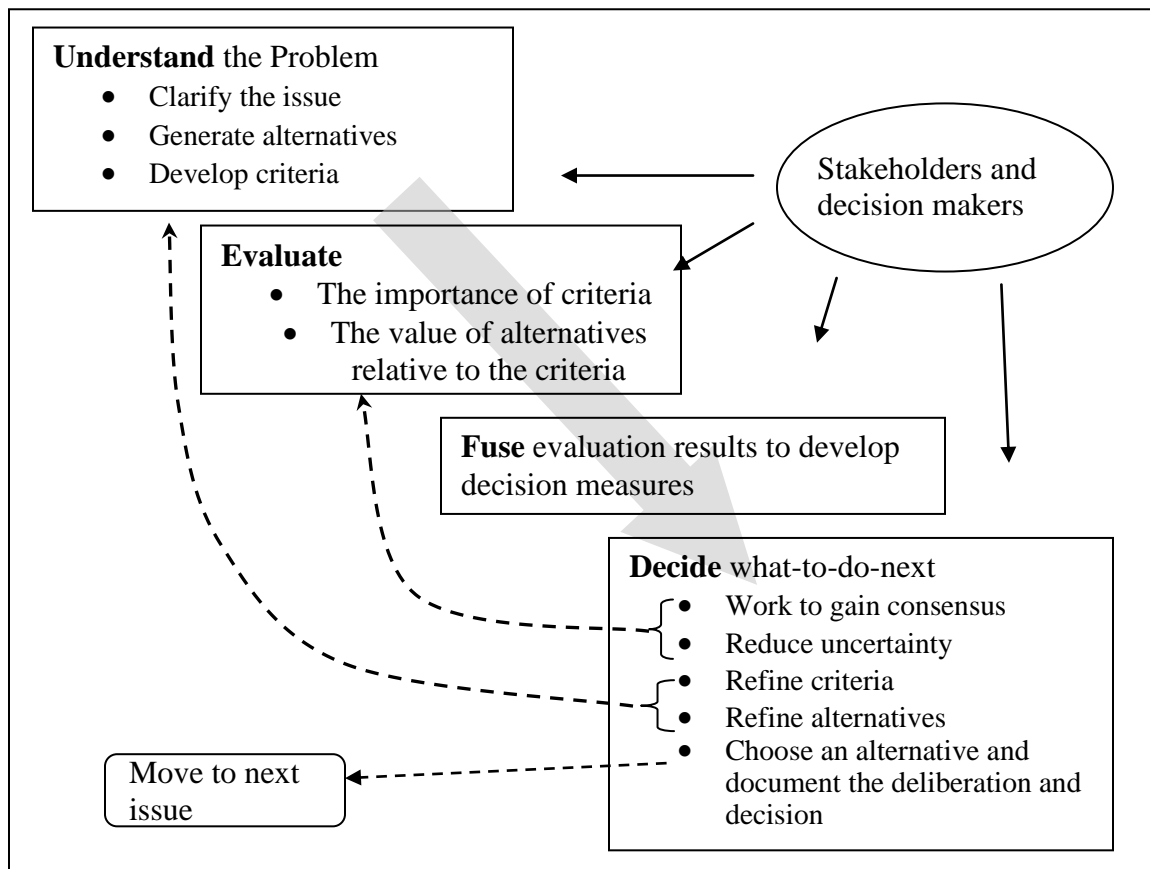


Figure 3, Decision-making Process

For an AoA, the following apply to the items in Figure 3:

- The issue is, “Choose the best solution before committing resources.”
- The alternatives are the projects or proposed solution sets. The value of the study is only as good as the options proposed and evaluated.
- The criteria are the measures for evaluating the alternatives. The USAF *Handbook* spends a considerable effort on how to construct criteria (i.e., MOEs) that can lead to a good study.
- Evaluations have two components: evaluating how important each of the criteria is for the stakeholders; and assessing the value of the alternatives by comparing them to the criteria. The USAF *Handbook* is very strong on the evaluation of the alternatives relative to the criteria. There are two “however’s.”
 - All evaluations are uncertain, and this uncertainty needs to be identified and analytically included as part of the qualitative and quantitative evaluations.
 - The importance held by each of the various stakeholders may be inconsistent. One way to build decision buy-in is to honor each of these viewpoints in the analysis.
- Decisions depend on fused evaluation results. Fusion has three difficult factors:

- Evaluations are often a mix of qualitative and quantitative. These must be combined in some consistent manner.
- Evaluation results might come from multiple sources and may be inconsistent with one another. This is especially true for qualitative evaluations.
- Evaluation results are uncertain and the uncertainty must be fused in a logical manner.
- Based on the fused results, decide “what-to-do-next.” This decision will direct the process down one of three possible paths:
 - Improve understanding: refine the alternatives and criteria
 - Refine evaluation: work to gain consensus and reduce uncertainty
 - Select an alternative

One feature of Figure 3 is that two of the paths leading from “decide what-to-do-next” go back to earlier activities. These arrows emphasize the information evolution and refinement that are inherent in making a robust decision. The diagram also shows that the stakeholders are involved in all parts of the decision-making process.

Conclusion: AoA in Context

The effectiveness of an AoA depends upon the decision-making context in which it is implemented. Attempting to use an AoA in the context of reactive, quick knee-jerk decision making is an exercise in futility. An AoA simply will not work in this type of framework. Knowledge-based decision making may or may not be conducive to the use of AoA; that would depend on the quality of the data, information, and information used for decision making.

Systematic decision making may or may not use an AoA in a documented, repeatable process. Similarly, aligned decision making strengthens the use of AoA by connecting the decision-making process to organizational purpose, vision, mission, strategies, goals, objectives, plans, programs, projects, routine tasks, and performance metrics. Integrated decision making, by considering internal and external factors and stakeholders, is an even more robust context for an AoA.

Architected decision making is the framework that enables the most robust criteria-based decision making. Framing decisions within a holistic context of the enterprise’s people, processes, technology, leadership/ management infrastructure, and change-management approach, and *forcing* decision makers to construct criteria that reflect the totality of the organization’s architecture, provides the most promise of decision making and decisions. It is in this type of framework where Analysis of Alternatives will yield the most effective and useful decisions.

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