

Decisions Based on Analysis of Alternatives (AoA)

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Analysis of Alternatives (AoA) is a term 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 costly investment decisions. AoA is an effort to move from the justification for a single alternative to the exploration of multiple alternatives so agencies have a basis for funding the best possible projects in a rational, defensible manner considering risk and uncertainty. As with other decision-making tools, techniques, and methodologies, AoA is most effectively used in a higher-level decision-making context, such as an Enterprise Architecture (EA) framework. In fact, it is doubtful that the higher levels of AoA maturity (see below) could even be considered outside of a higher-level context.

What Is AoA? And Why Do It?

Analysis of Alternatives is the analytical comparison of multiple alternatives to be completed before committing resources to one project. The practice of comparing multiple alternative solutions has long been a part of engineering practice (Ullman, 2009, especially Chapter 7, Concept Generation). There is, however, a natural human tendency to propose a single alternative for funding or development and justify this option rather than compare multiple options with the goal of choosing the best one. Justification is easier to do than evaluating multiple options and making a learned decision. Thus, government agencies like OMB and DoD have found it necessary to encourage those proposing projects to use AoA.

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

- Level 0 – Propose one alternative and justify it.
- Level 1 – Propose multiple alternatives and provide a one-dimensional comparative analysis with weak inclusion of uncertainty effects.
- Level 2 – Propose multiple alternatives and provide multi-dimensional comparative analysis with weak inclusion of uncertainty effects.
- Level 3 – 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. More levels could be defined by considering these measures separately, but these four levels are sufficient for the current state-of-the-art.

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This paper will show how OMB pushes funding approval from Level 0 to Level 1, and how DoD encourages Level 2 AoA. Further, the paper will show that current AoA methods only go part of the way to achieving the highest potential – i.e., Level 3 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 promise will be explored.

AoA's Value Depends on Estimation and Risk

The “analysis” in AoA refers to making estimates of future costs, 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 sources (11 such sources are discussed in *Making Robust Decisions*), and these can be characterized by the types of resulting risks: technical risks, programmatic risks, operational risks and decision risks. The first three are often discussed; but the last one, decision risk, the risk of choosing the wrong alternative when performing an AoA, needs to also be known. Before discussing risks, some background on estimation accuracy is in order.

Estimations about time, cost, or performance are notoriously inaccurate. In one government agency, cost overruns range from 31% (small projects) to 315% (very large projects). As another example of estimation inaccuracy, in the *Chaos Report* (Standish Group, 2000 and 2004) an annual analysis of 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 and self-serving.

In a simple estimation exercise (described in detail in *Making Robust Decisions*), time estimates were made for a simple, 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 noisy guess.

Risk is due to uncertainty: without any uncertainty, reality will match the estimate and the risk will be zero. Formally, risk is the combination of the likelihood of something going wrong times the consequences if it does. The goal of including uncertainty in AoA is to help in analyzing risk. In terms of the example estimation exercise in the previous paragraph, it should be possible in an AoA evaluation to include the uncertainty in the time estimates as they may have a marked effect on the alternative evaluations and the

decision made. With this brief background, the AoA efforts by OMB and DoD are introduced.

AoA, An OMB 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 0 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 1 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 weaknesses:

- 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 pulling numbers out of the air, 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 hopelessly 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 0 policies to Level 1 using solely NPV. NPV is certainly one appropriate measure, but it is not the only measure that should be included in AoA. As described in the next section, DoD pushes AoA much further.

AoA, the DoD Effort

In DoD AoA is used in the decision-making process to support acquisition of new capabilities and systems. Each Service has its own AoA methodology, but the best documented (and an adequately representative method) is detailed in the Air Force Materiel Command *Analysis of Alternatives (AoA) Handbook* (USAF, 2008). It is, as the title states, a handbook full of useful tools and techniques. We will use material from it in this discussion.

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 2.

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. Effectiveness measures are generally referred to as Measures of Effectiveness (MOEs). As paraphrased from the handbook, 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 3. 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 the 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 all of the analysis has finalized, 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 is still weak in two areas, handling of uncertainty and a decision centric approach to the problem.

AoA, The Promise

As stated in the introduction, the ultimate goal of AoA is to support making robust resource allocation decisions. Where OMB pushes Federal agencies to Level 1 AoA and the DoD manages Level 2, neither meets the qualifications for Level 3. In this section we will explore what it will take to meet the stated definition:

Level 3 – 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 not well supported. The following describes what is needed to fulfill all these AoA needs.

It can seem that AoA is a requirement to do analysis for analysis' sake unless the final goal is kept in sight: from a suite of alternatives, choose the one most likely to be successful or identify what needs to be done next to make this decision. Thus, AoA should center on the elements of a decision process. As shown in Figure 3 (taken from *Making Robust Decisions*), there are four main activities necessary for information (i.e., data, models, and knowledge) 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.

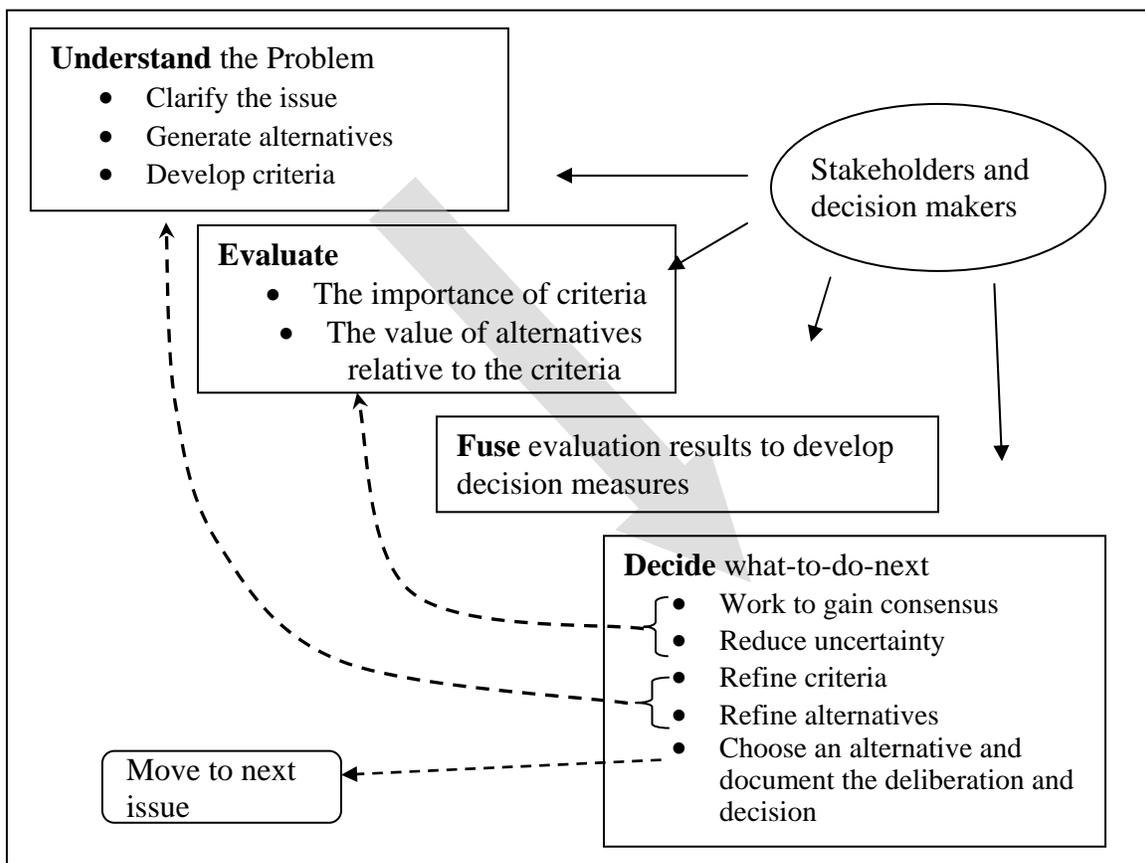


Figure 3, Decision-making Process

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

- The issue is, “Choose the best project before committing resources.”
- The alternatives are the projects. The value of the study is only as good as the projects proposed and evaluated. In the early days of the OMB policy, alternatives were sometimes crafted to lead to the desired conclusion.
- The criteria are the measures for evaluating the alternatives. The USAF *Handbook* spends much 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 values (i.e., 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. In the words of Arthur C. Clark, “the only difficult decision in life is what to do next.” This decision will direct the process down one of three paths:
 - Improve understanding
 - Refine alternatives
 - Refine criteria
 - Refine evaluation
 - Work to gain consensus
 - Reduce uncertainty
 - Choose 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 and decision makers are involved in all parts of the decision-making process.

We are exploring the use of Accord™² to support AoA Level 3 studies. This is a tool specifically designed to support engineering decision making. It is Bayesian-based and supports the flow and analysis given in the figure. It is especially strong in its support of uncertainty, team analysis fusion, and guiding what-to-do-next.

Conclusion: AoA in Context

It must be noted that the effectiveness of AoA will depend upon the decision-making context in which it is implemented. Attempting to use AoA in the context of reactive, knee-jerk decision making is an exercise in futility. 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 knowledge used for decision making.

Systematic decision making may use AoA in a documented, repeatable process ... or it may not. Similarly, aligned decision making, almost by definition, strengthens the use of AoA by connecting the decision-making process to organizational purpose, vision, mission, strategies, goals, objectives, plans, programs, projects, routine work and tasks, and performance metrics. Integrated decision making, by considering internal and external factors and “players,” is an even more robust context for AoA. But still, aligned and integrated decision making may not bring out the best in AoA; consequently, the decision making process may not be as robust as possible.

Architected decision making – within, say, an Enterprise Architecture framework – is the context 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 robust decision making and decisions. It is in this type of framework where AoA will yield the most effective and useful decisions.

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² See details on Accord at www.robustdecisions.com

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