

# Analysis of Alternatives (AoA) Based Decisions

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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 from 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.

## What Is AoA?

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 decision. Thus, government agencies such as OMB and DoD require the use of a rigorous AoA process when proposing program solutions.

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 some inclusion of uncertainty effects.
- Level 2 – Propose multiple alternatives and provide multi-dimensional comparative analysis with some 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 are based on 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.

This paper will show how OMB calls for funding approval at Level 1, and how DoD sets a goal to achieve Level 2 AoA. Further, the paper will show that current AoA methods only go part of the way to achieving the highest potential – Level 3 AoA. Keep in mind

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that the ultimate goal of an AoA exercise is to enable 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, and then AoA's potential is 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* (ULL2006) 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<sup>3</sup>, 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 after performing an AoA, is often omitted and should be assessed.

Time, cost, and performance estimations are notoriously inaccurate. In one government agency, cost overruns range from 31% (small projects) to 315% (very large projects)<sup>4</sup>. As another example of estimation inaccuracy, in the *Chaos Report* (STA2009) an annual analysis of information technology (IT) projects, 44% of all IT projects were delivered late or over budget and an additional 24% were cancelled. Only 32% projects completed were on time and budget with full functionality. 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 how long it will take to clean a pile of dirty dishes, by hundreds of attendees at a conference. Even though the list of dirty dishes was very detailed, 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 common task 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 possible in an AoA to include the uncertain time estimates as they may have a marked impact on cost and material estimates when it comes to making decisions.

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<sup>3</sup> (ULL2006) page 66

<sup>4</sup> (ULL2006) page 75

## The Office of Management and Budget AoA Effort

Part 7 (Section 300) of the OMB Circular A-11 (OMB2008) 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* (GSA2007).

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:

- Alternatives Analyzed
- Description of Alternatives
- 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* says 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 to actually commit 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 dollars. Time is money, but time estimates are often inaccurate.

In concluding an AoA study for the OMB, an 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 detail and rigor of a cost benefit analysis should be commensurate with the size and complexity of a project. Cost/benefit projections should be calculated for all viable alternatives.

OMB and GSA give little guidance to address the risks in the estimates. The best to be found is in Section 9 of *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (OMB2006). According to which, estimates of benefits and costs are typically uncertain because of imprecision in both underlying data and modeling assumptions. The guidance 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.

OMB forces AoA Level 0 policies to Level 1 using solely a cost basis. Cost is certainly one appropriate measure, but it is not the only measure that should be included in an AoA. As described in the next section, DoD pushes AoA much further.

## **The Department of Defense AoA Effort**

DoD typically applies AoA to support acquisition decisions. By definition, “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”<sup>5</sup>. DoD instruction 5000.2 (DOD2008) provides AoA procedural guidance for potentially high cost projects referred to as Acquisition Category 1 (ACAT 1 or 1A) programs. The procedure describes the requirement of the Milestone Decision Authority (MDA) to approve AoA guidance for the service lead or the Principle Staff Assistant (PSA) in charge of the mission area. The service lead or PSA in turn designates responsibility to complete the AoA study plan. In order to avoid conflict of interest, the program manager (PM) is not assigned that responsibility. The AoA study plan must be approved by the MDA prior to the start of the AoA. The Office of the Secretary of Defense’s Cost, Assessment & Program Evaluation office (CAPE - formally known as Program Analysis & Evaluation (PA&E)) provides an independent assessment of the AoA to the MDA in the following goals<sup>6</sup>:

- Illuminated capability advantages and disadvantages
- Considered joint operational plans
- Examined sufficient feasible alternatives
- Discussed key assumptions and variables and sensitivity to changes in these
- Calculated costs
- Assessed technology risk and maturity, alternative ways to improve energy efficiency, and appropriate system training

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<sup>5</sup> (DoD, 2008), page 15

<sup>6</sup> (DoD, 2008), page 58

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. 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 a level of specificity that would hamper analytical organizations from tailoring each AoA to individually assess and evaluate the potential program<sup>7</sup>. The Army’s TRADOC Analysis Center (TRAC) often is responsible for the conduct of ACAT 1 and 2 programs while the mission area leads (school houses) are responsible for less costly programs.

Similar to the Army, the Assistant Secretary of Navy Research, Development and Acquisition (ASN (RDA)) releases guidance on AoA preparation and how to prepare a proposal in coordination with major stakeholders (USN2008). 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, methodology, and approach<sup>8</sup>.

Perhaps the best documented AoA methodology and approach is detailed in the Air Force Materiel Command *Analysis of Alternatives (AoA) Handbook* (USAF2008). It is a handbook of useful analysis tools and techniques. We will use material from it in this discussion.

DoD AoA studies span across 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 similarly 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 an AoA and consumes significant resources. Effectiveness analysis attempts to

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<sup>7</sup> (DA, 2009), page 4. (DA, 2010), page 13, 18, 24. (DA, 2011), page 22. .

<sup>8</sup> Defense Acquisition University, Analysis of Alternatives, April 2006 page 4.

determine the military worth of alternatives relative to qualitative or quantitative measures. These focus on a system's performance or characteristics indicating the degree to which it performs its objective. 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 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 is to make a decision but it does not provide sufficient guidance to achieve 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.

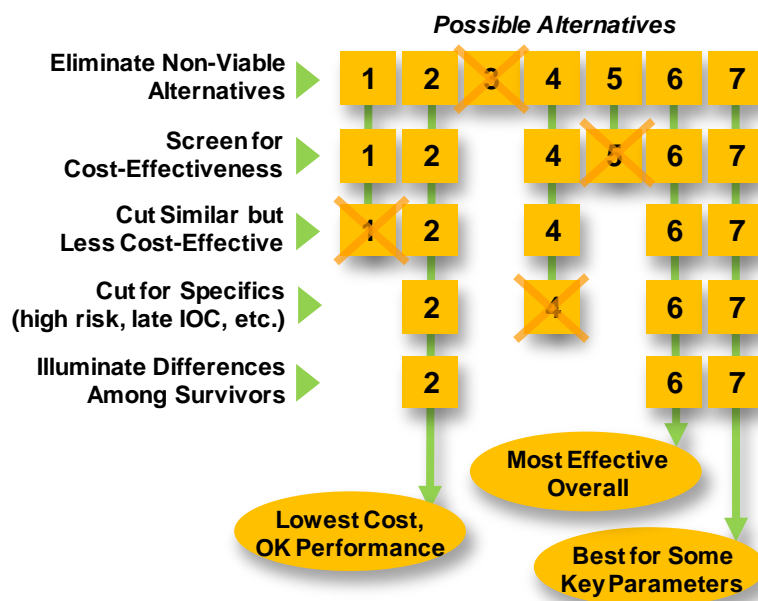


Figure 1, Filtering of Alternatives

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* (ULL 2009)), is strong, but grows weak when discussing how to select among the finalists (Options 2, 6, and 7, in Figure 1).

What is suggested is that plots of cost versus effectiveness be made to support 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 assess 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 key discriminators for each alternative side-by-side, before presenting the conclusions and recommendations. Figure 2 shows an example of this type of presentation, an alternative comparison matrix, where LCC represents Life Cycle Cost. This depiction ensures that the reader or briefing audience has a summary picture of the results in mind 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 address the high-level issues from the AoA guidance.

Where the DoD approach to AoA is more mature than that of OMB, it is not evenly applied and could to be extended to Level 3.

## Lessons Learned from DoD AoA Efforts

In 2009 the GAO was tasked with studying how well AoA efforts ensured that DoD projects met time and cost targets (GAO2009). To accomplish this they studied 32 major acquisition projects. The goal was to assess “(1) whether AoAs have been effective in identifying the most promising options and providing a sound rationale for

weapon program initiation, (2) the factors that affect the scope and quality of AOA, and (3) whether recent DOD policy changes will enhance the effectiveness of AOA. Their results can be itemized as six measures of AOA adequacy:

**Range of Alternatives Developed:** Of the 32 projects studied, there was no formal AOA in ten of them. Of these, seven were updates of earlier projects or were supported by other analyses. For the other 3, high cost and schedule growth occurred as shown in Figure 3. Of the remaining 22 projects,

13 were supported by a limited AoA – narrow scope of alternatives – and these resulted in nine with moderate to high cost or schedule overruns while the nine that included a broad scope of alternatives only resulted in two with moderate to high overruns. Another way to look at the data; 12/23 (52%) failed with no or limited alternative development while 2/9

(22%) failed with good alternative development. If those seven that were updates of earlier projects or supported by other analyses are not counted then the failure rate for projects without AoA support is 12/16 (75%).

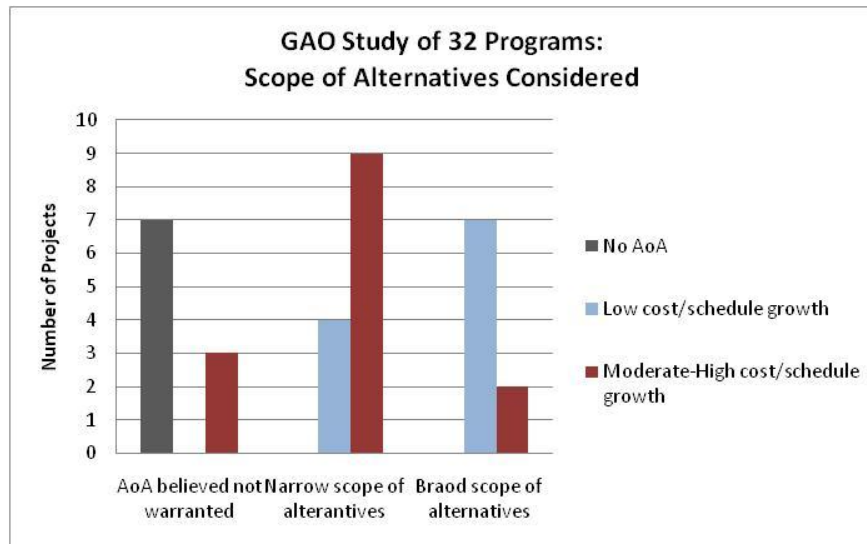


Figure 3: GAO Report Results – Range of Alternatives

**Adequacy of Risk Assessment:**

Twelve of the 22 AoA projects conducted limited or no risk assessment for each alternative as shown in Figure 4. Of these 12, eight experienced moderate to high cost and schedule overruns. The other 10 projects were judged to have adequate assessment of risks. Of these, three resulted in moderate to high cost or schedule overrun. The GAO report concluded from these results that, AOA that do not examine risk present overly optimistic assessments of the alternatives.

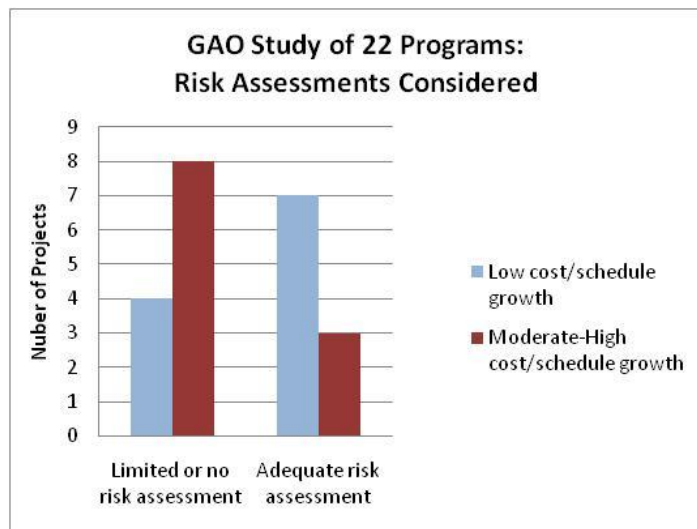


Figure 4: GAO Report Results – Risk Assessment

**Timing of Alternative Selection:**

Choosing an alternative too early exacerbates overruns. Of the six projects that chose too early, all of the four that did not develop sufficient alternatives or adequate risk assessment had moderate to high overruns (first columns in Figure 5). In these four, the program sponsors had decided on a preferred solution prior to the AoA. The AoA was more of a justification exercise. The two projects that, in spite of early selection, still had time to explore multiple alternatives and perform adequate risk assessment had low cost and schedule overruns.

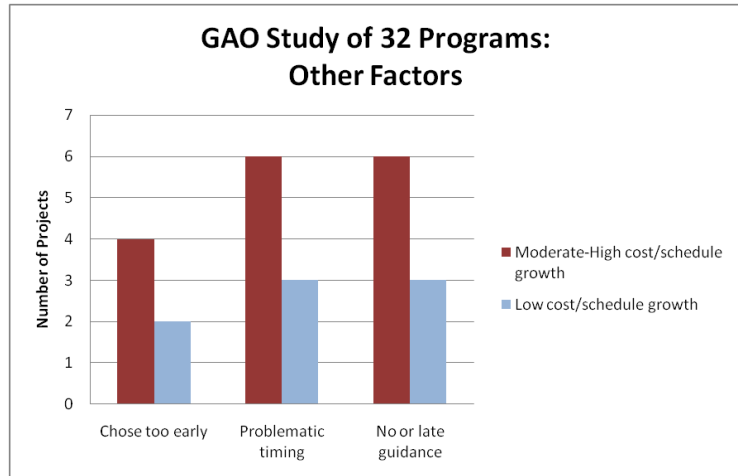


Figure 5: GAO Report Results – Other Factors

**Time spent on AoA:** In nine projects, the AoA study was compressed or concurrent with other activities. Seven of these also did not develop sufficient alternatives or adequate risk assessment. As shown in the second set of columns in Figure 5, of these seven, six had high overruns due to problematic time committed to the AoA study. The two that still had time to explore multiple alternatives and perform adequate risk assessment, had low cost and schedule overruns.

**Guidance for Conducting an AoA:** Of the 22 projects 9 were provided with late or no guidance at all. Of these nine, six did not develop sufficient alternatives or adequate risk assessment. Of these six, five had high overrun. Of the three that explored multiple alternatives and performed adequate risk assessment, two had low cost and schedule overruns. In all, six of the nine were late and over budget as shown in the last set of columns in Figure 5.

**Alternative Risk Comparison:** It is especially important to compare risks for new programs. For the eight new development starts only four did adequate risk comparison. Of the four that did not, at least three had high cost and schedule overruns as shown in Figure 6.

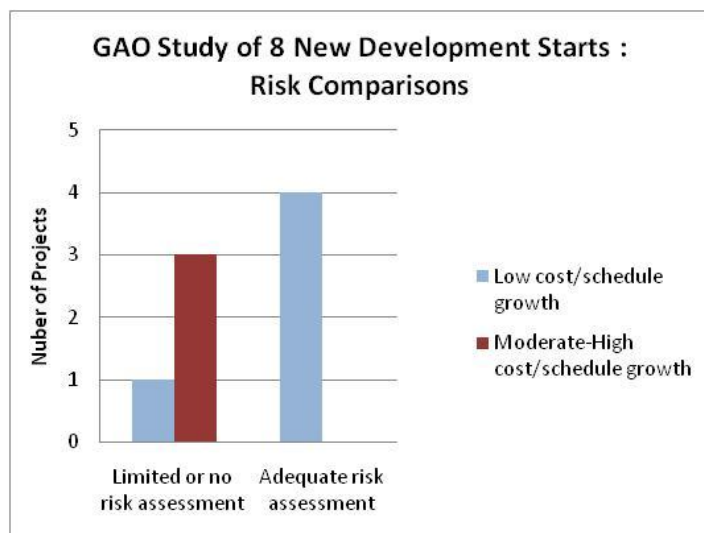


Figure 6: GAO Report Results – Risk Comparison

In the conclusions of the AoA report, the authors state: “A robust AoA can be a key element to ensure that new programs have a sound, executable business case”.

Further, they conclude “*While many factors can affect cost and schedule outcomes, we found that programs that had a limited assessment of alternatives tended to have poorer outcomes than those that had more robust AoAs.*” .... “*The narrow scope and limited risk analyses in AoAs can be attributed in part to program sponsors choosing a solution too early in the process, the compressed timeframes that AoAs are conducted under, and the lack of guidance for conducting AoAs.*”

## Taking AoA to the Next Level

As stated in the introduction, the ultimate goal of AoA is to support robust resource allocation decisions. Where OMB pushes Federal agencies to Maturity Level 1 and the DoD calls for Level 2, neither’s guidance meets the qualifications for Level 3. In this section we will explore what it takes 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.

Level 3 AoA maturity requires ten key components as shown in Table 1. The bold X indicates that the component is included in the level and the gray X indicates that it is partially included. As stated before, OMB requires Level 1 maturity – focus on multiple alternatives (#1) and life cycle cost (#2). While it does require risk assessment (#5), it is a narrow, cost basis and which does not capture other project uncertainties. Also, it requires alternative comparison (#7), but as will be shown, this too is not strong. Finally, The OMB provides a very rigorous reporting format (#10) for identification of the best alternative (#9).

DoD requirements are at Level 2 maturity - adding the requirement to explore multiple criteria (i.e. Measures of Effectiveness) (#3) and the evaluation of the alternatives relative to them (#4). DoD requires risk assessment (#5) but it is not as broad as it could be. The Air Force *Handbook* provides guidance for a tabular method to compare alternatives (#7).

	Ten Key AoA Components	Level			
		0	1	2	3
1	Develop Multiple Alternatives		<b>X</b>	<b>X</b>	<b>X</b>
2	Evaluate Lifecycle Cost		<b>X</b>	<b>X</b>	<b>X</b>
3	Define Criteria			<b>X</b>	<b>X</b>
4	Evaluate Alternatives versus Criteria			<b>X</b>	<b>X</b>
5	Evaluate Effect of Uncertainty/Risk		X	X	<b>X</b>
6	Build Stakeholder Buy-in				<b>X</b>
7	Compare Alternatives		X	<b>X</b>	<b>X</b>
8	Decide What To Do Next				<b>X</b>
9	Select Best Alternative		<b>X</b>	<b>X</b>	<b>X</b>
10	Report Results		<b>X</b>	<b>X</b>	<b>X</b>

Table 1: The Ten Key AoA Components

Two components missing from both current methods are; building stakeholder buy-in (#6)<sup>9</sup> and guidance about what to do next (#8)<sup>10</sup> For many projects there are multiple constituents, each of who has a stake in the outcome and needs to be enfranchised in the process. While it is not the intent of the OMB and DoD methods to accomplish this additional task, it can be a major part of an AoA exercise as will be shown in the example below. Further, since the evaluations are based on uncertain estimates, one result of the AoA is to spend more time and resources on certain measures to improve their fidelity prior to making a choice. In other words, the results of an AoA exercise can provide guidance about what additional efforts to fund rather than choosing a single, best alternative.

One project pushing AoA to Level 3 maturity is funded by BOEMRE (Bureau of Ocean Management, Regulation and Enforcement)<sup>11</sup> to develop a computer based tool to help choose the best locations for wave energy devices off the Oregon Coast. The data used to support the selection amongst the alternative sites is a combination of scientific data, government regulations and constituent values and opinions. Thus, this AoA exercise is broader than the “acquisition” problems faced by OMB and DoD. It is dominated by 1) uncertain information where the uncertainty is across all measures 2) the wide range of constituents and the need for buy-in from them all, and 3) the desire to identify what new information is needed to improve the quality of the choice.

The scientific data about the ocean, the flora and fauna that live in it and people’s use of it is uncertain, incomplete, conflicting and evolving as new information is collected. Further, the stakeholders have strongly held opinions and values that must be integrated. To reflect this uncertainty and risks inherent in the project, the scientific data and other information will be combined using Bayes Nets, a probabilistic methodology that allows the certainty of the information to be reflected in the satisfaction of each alternative. This analysis will greatly enhance the evaluation of risks (#5) while build stakeholder buy-in (# 6).

Further, to capture opinion and values, the stakeholders will be using an interactive, web based tool to compare alternatives (#7). This is designed to enhance the stakeholder experience and feeling that they are a part of the decision-making process.

A benefit of using Bayesian analysis is that it can actually calculate which evaluations are most sensitive to the uncertainty and thus, represent the greatest risk. With this information, additional scientific information can be collected, or effort put into building consensus amongst stakeholders with clear knowledge about which efforts will improve the alternative selection process.

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<sup>9</sup> (ULL2006) pages 96 and 236

<sup>10</sup> (ULL 2006) pages 245-258

<sup>11</sup> This project began in November 2010 and thus, there are no references for it. The first author is a Principle investigator in the project.

## Conclusion: AoA in Context

In this paper we have shown that AoAs are a reaction to justifying one idea and throwing resources at it (i.e. time and money) until it works. Rather, it front loads the acquisition, structural or organizational change process with detailed study of multiple alternatives and a logical process to find the one most likely to be successful. The use of resources early is generally much less expensive than later. It cost less to modify the direction of a project when the effort is on paper (during AoA) than after funds have been spent on hardware and organizational changes. In the acquisition of new hardware, a design change (choosing a different alternative) may cost thousands, were as a hardware change could cost millions.

While people seem to be naturally wired to make their favorite idea a reality, the AoA process tries to slow them down so they are forced to consider the alternatives. But even the OMB and DoD requirements do not go far enough as, early in the alternative selection process, uncertainty and other factors may have an impact that must be taken into account. Even though these organizations are headed in the right direction, the AoA processes they require have room for further maturity.

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