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# Military Cost-Benefit Analysis: A Multi-Attribute Three-Stage Procurement Model

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# Introduction

- Large & rising federal debt, shrinking discretionary budget
  - Budget uncertainty!
- Defense procurement typically requires vendors to submit bids which include
  - Price
  - Performance attributes
- Problem: Optimal vendor choice may change with changes in the budget!

# Budget Constraint

- Based on an "Economic Evaluation of Alternatives" (EEoA)* approach:
  - The procurement agency buyer reveals desired attributes and the budget for the program
  - Vendor offers (bids) consist of product proposals to produce a set of performance attributes for a given budget authority
  - The procurement agency buyer selects a vendor according to the buyer's ("secret") weighting of the attributes (i.e. a multi-attribute value function)

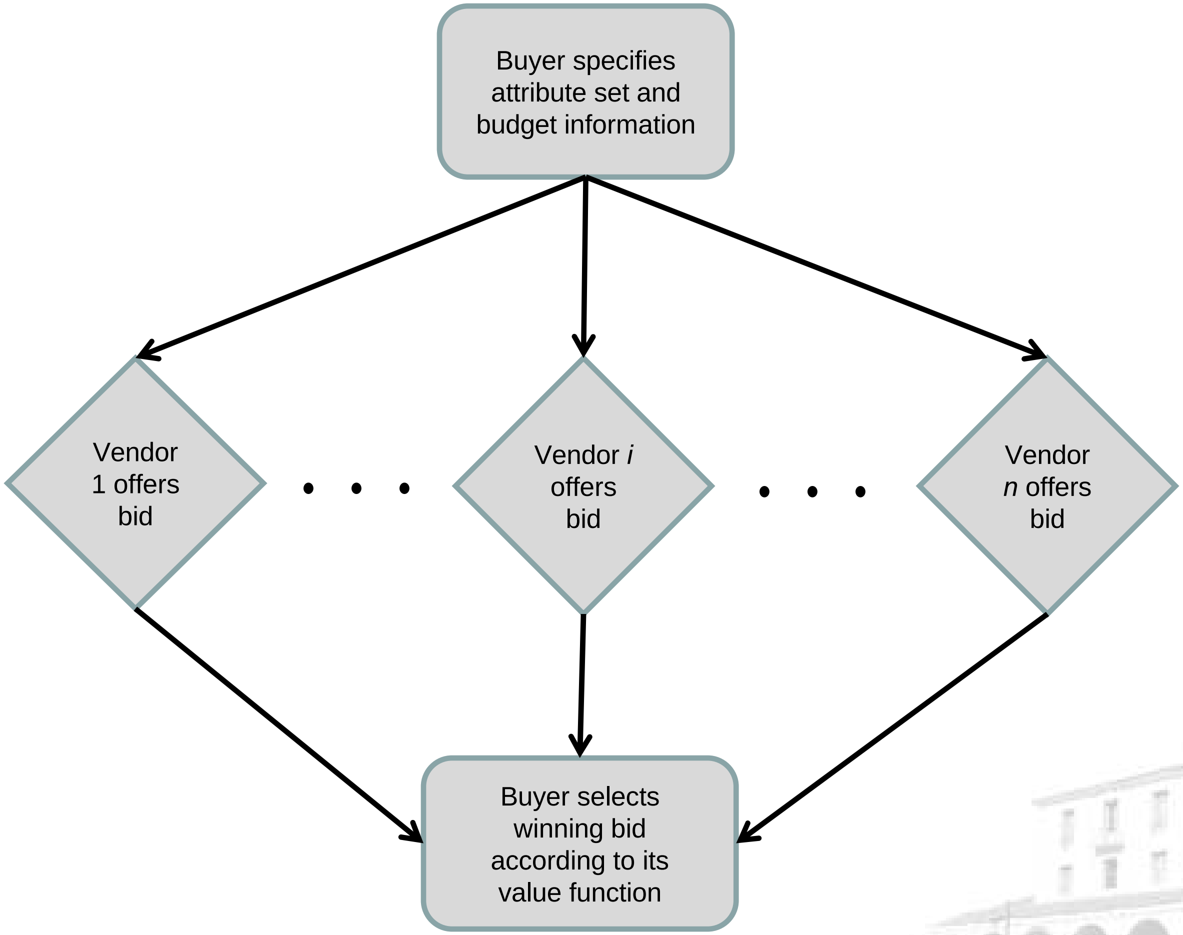
* See pp. 25-28 in Melese, F. "The Economic Evaluation of Alternatives," Proceedings of the 6th Annual Acquisition Research Symposium: Defense Acquisition in Transition, Vol 1.

# Model Structure

Stage 1

Stage 2

Stage 3



# Model

- *n* vendors
- Set of attributes *A* (1,…,*m*)
- Vendor *i*'s offer is $A_i = [a_{i1}, \ldots, a_{im}]$
- Buyer's "secret" value function (MOE) is $V(A_i)$
- Budget level is *B*
- Buyer makes selection decision according to:

$$\max_i \quad V(A_i) = \sum_{j=1}^{m} w_j a_{ij}$$

# Vendor's Decision Problem

- Private information on production capabilities and costs:
  - Captured by cost functions $c_{ij}\left(a_{ij}\right)$
- Does not know *V*, but forms beliefs about the buyer's preferences
- "Best guess" $\gamma_i = \left(\gamma_{i1},\ldots,\gamma_{im}\right)$
- Results in a hypothetical value function to maximize: $Q\left(A_i\right) = \sum_{j=1}^{m} \gamma_{ij} a_{ij}$

# Vendor's Decision Problem

- Vendor *i*'s problem can be expressed as:

$$\max_{a_{ij}} \quad Q\left(A_i\right) = \sum_{j=1}^{m} \gamma_{ij} a_{ij}$$

$$\text{s.t.} \quad TC_i = \sum_{j=1}^{m} c_{ij}\left(a_{ij}\right) \le B$$

# Simplified Approach

- For the sake of clarity, the remainder of the analysis will assume:

**Two attributes**

**Two vendors**

# Solution to Vendor's Problem

- A vendor's best offer (bid) will be a combination of attribute levels that uses the entire budget, and satisfies the condition:

$$\frac{\gamma_{i1}}{c'_{i1}(a_{i1})} = \frac{\gamma_{i2}}{c'_{i2}(a_{i2})}$$

- The buyer then chooses the vendor that maximizes its military effectiveness value, *V*, for the planned budget, *B*

# Budget Uncertainty

- Now, instead of *B*, consider a range of possible budgets: $B_1, \ldots, B_k$
- Each vendor submits an offer (bid) for each of the *k* possible budgets
- This set of offers from a vendor constitutes an "expansion path"

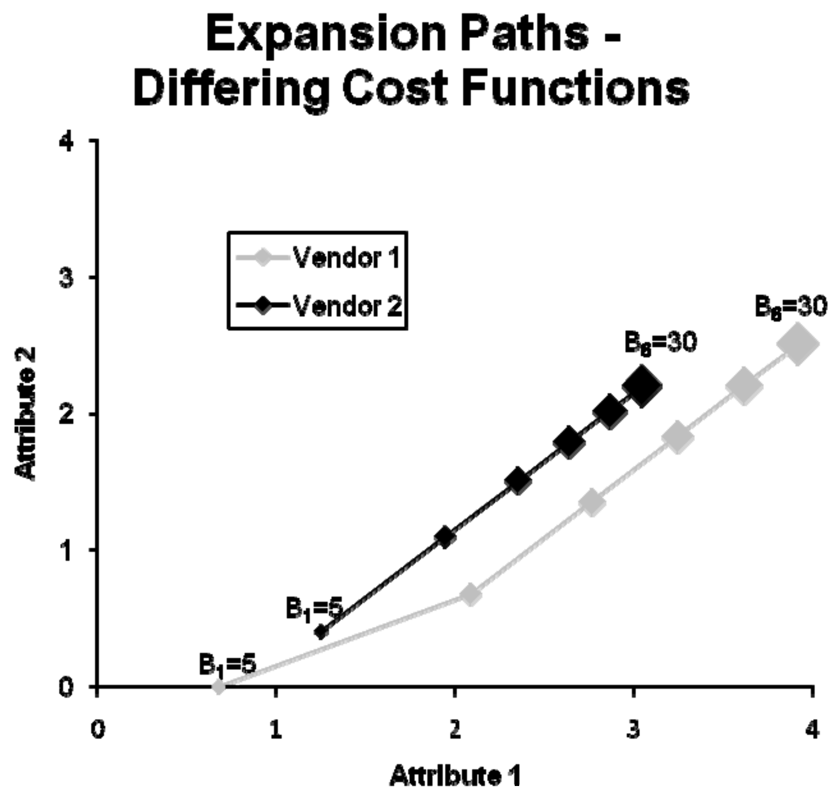
# Examples

- Let the vendors have cost functions of the form:

$$c_{ij}\left(a_{ij}\right)=\alpha_{ij}e^{\beta_{ij}a_{ij}}, \text{ where } \alpha_{ij},\beta_{ij}>0$$

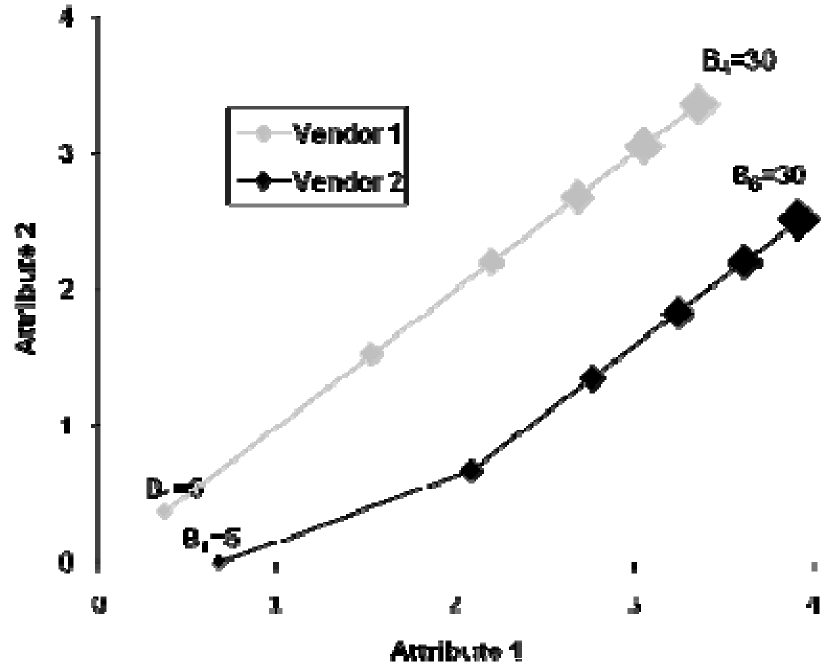
- $B_1$=5, $B_2$=10, $B_3$=15, $B_4$=20, $B_5$=25, $B_6$=30

- We will examine several cases where the vendors differ in their cost functions and/or beliefs about the weight the buyer places on the attributes




$$\alpha_{11} = \alpha_{12} = 2.0, \beta_{11} = \beta_{12} = 0.6, \alpha_{21} = \alpha_{22} = 1.0, \beta_{21} = \beta_{22} = 1.0, \gamma_{11} = 0.7, \gamma_{21} = 0.7$$

# Expansion Paths - Differing Beliefs (γ)

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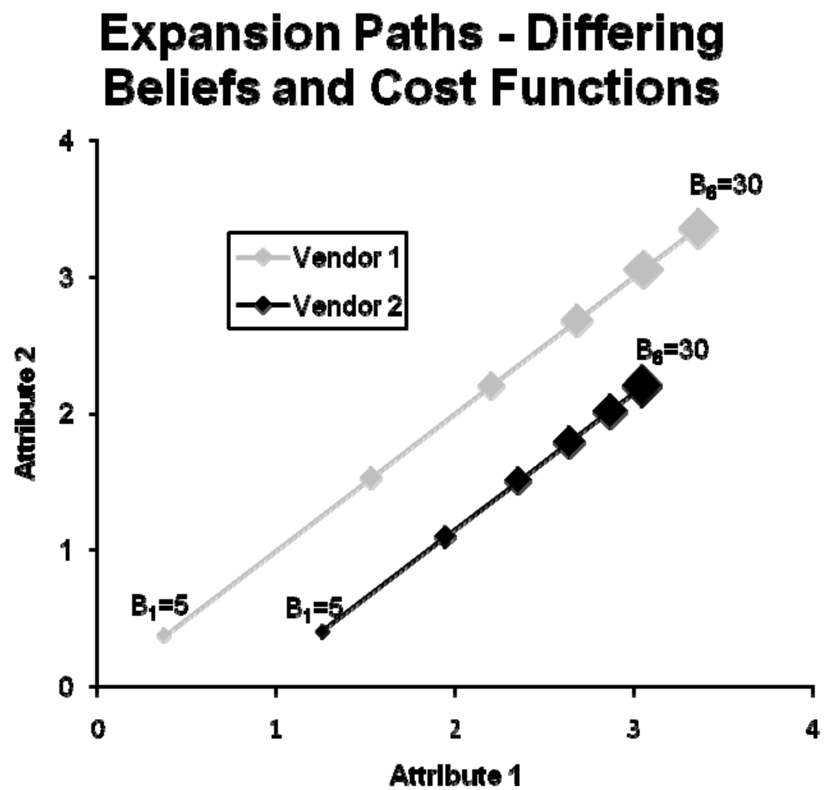


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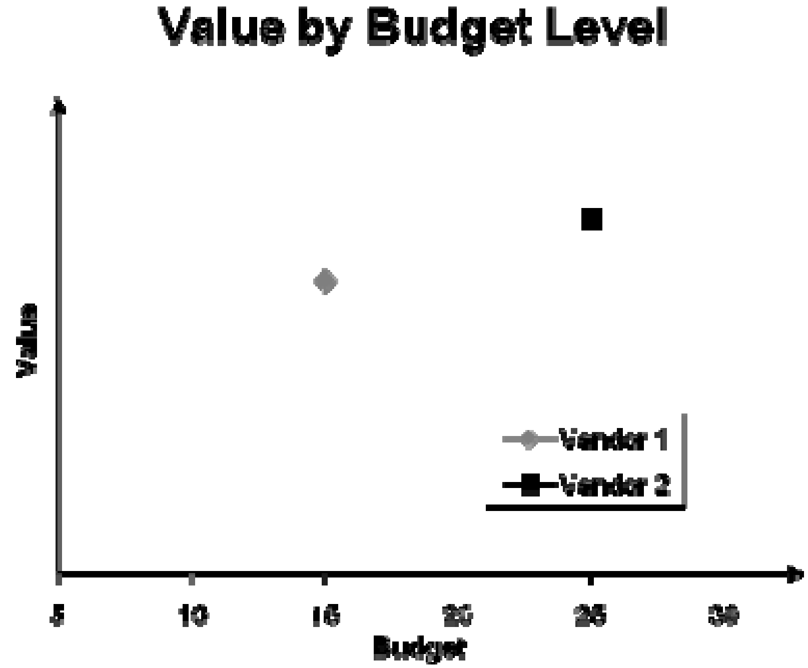
# Switch to Budget-Value Space

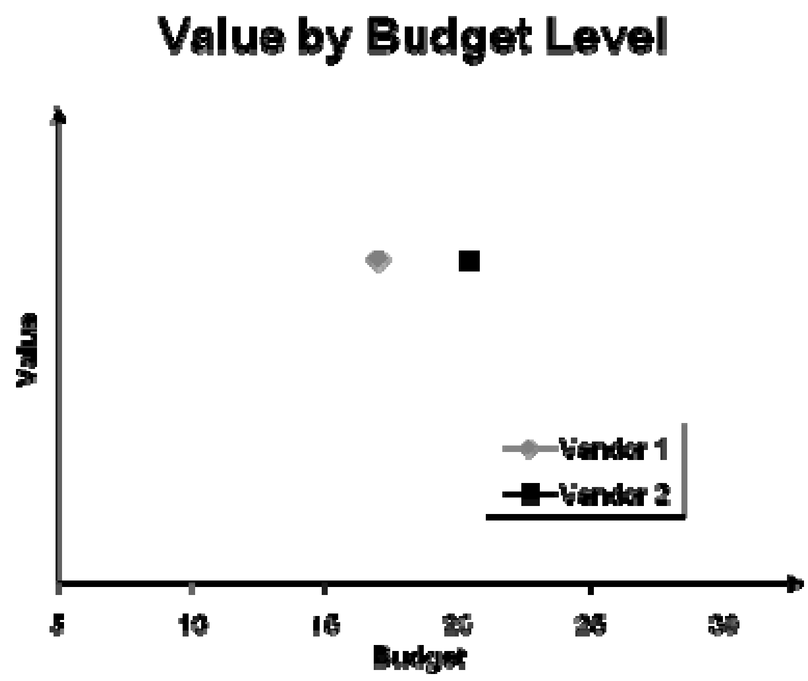
- What is the value to the buyer (procurement agency; warfighter) provided by each vendor for a specific budget authority?
- What is the value to the buyer provided by each vendor over all possible budget levels?

- Assume the two vendors have the properties from the last graph, and that the buyer places a weight of 0.7 on attribute 1

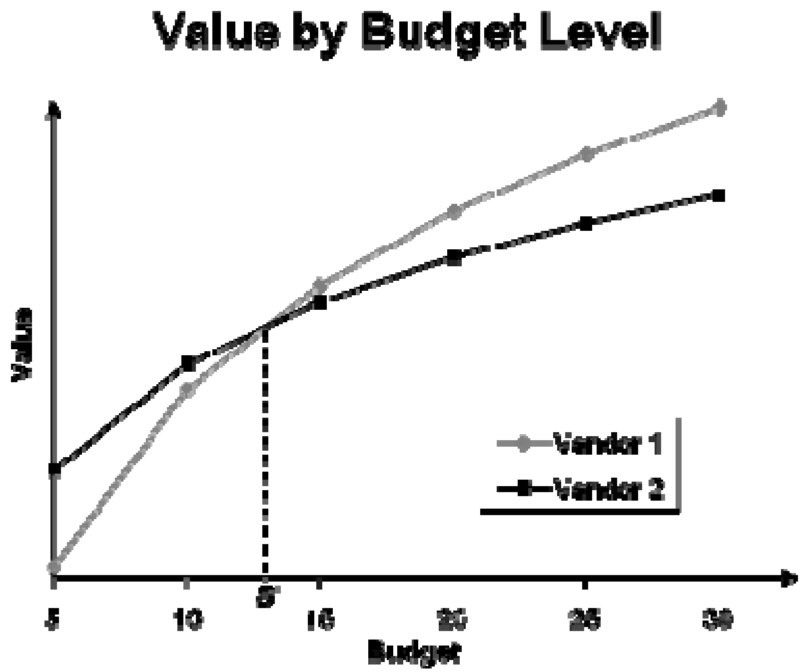
# Traditional Price & Performance Bid



# Air Tanker Costs for Given Level of Effectiveness (Boeing vs. EADS?)



# Vendor Bids:
# Performance Offers over a Range of Budgets



# Next Steps

- Model the budget uncertainty with a probability distribution, and determine the expected utility provided by each vendor
- Include uncertainty in vendor performance (quantity, quality, schedule) promises
  - May be framed as either cost uncertainty or performance uncertainty or both (depends on the particular contract structure)