Military Cost-Benefit Analysis: Introducing Affordability in Vendor Selection Decisions

Francois Melese, Jay Simon, Anke Richter

Defense Resources Management Institute (DRMI)
Naval Postgraduate School

Background

- Ballooning public debt forces DoD to rethink its procurement strategy.

- Congressional testimony urges DoD to “achieve a balanced mix of weapon systems that are ***affordable***”

(M. Sullivan, GAO 2009)

Background

Cost as an Independent Variable (CAIV)

- "Cost and ***affordability*** should be a driving force not an output after potential solutions are established."

(Larsen, 2007 p. 15)

Background

- Hitch and McKean (1967), advocate determining the maximum effectiveness for a given budget, and then examining how each alternative fares under several different budget scenarios.

- Quade (1989) advocates evaluating vendor proposals based on a range of possible budgets.

Introduction

- Procurement Goal:
  - Select vendors that deliver the best combination of desired non-price attributes at realistic funding levels.

- New approach to vendor selection:
  - Multi-attribute sealed-bid procurement auction with multiple budgets.

Introduction

- Goals:
  - Provide a more complete view of vendor's ability to perform under different budget scenarios.
  - Develop a new **Vendor Selection Metric (VSM)** for vendor selection decisions
- Three Stage Procurement Model
  1) Government offers a set of possible funding levels.
  2) Vendors offer proposals for each budget.
  3) Government selects vendor.
- "Expansion paths" for each vendor, reveal how vendor proposals change as funding changes.

Three Stage Procurement Model

- Based on "Economic Evaluation of Alternatives" (EEoA)*
  1) DoD reveals desired attributes and a set of possible funding levels for the program
  2) Vendor proposals consist of sets of non-price performance attributes for each possible funding level
  3) DoD selects vendors according to its weighting of attributes (i.e. a multi-attribute value/utility function)

* Page 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

- *n* vendors
- *m* attributes (*A*)
- *k possible* budget levels, *B* (1,…,*k*)
- Vendor offers $A_i = [a_{i1},\ldots,a_{im}]$ for each funding level
- DoD value function (MOE) is: $V(A_i)$
- **For each budget level, b, DoD's objective is**:

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

Vendor's Decision Problem

- For each possible budget level, *b*, Vendor *i*'s problem can be expressed as offering a mix of attributes that:

$$\max_{a_{ij}} \quad V\left(A_i\right) = \sum_{j=1}^{m} w_j v_j\left(a_{ij}\right)$$

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

Simplified Example

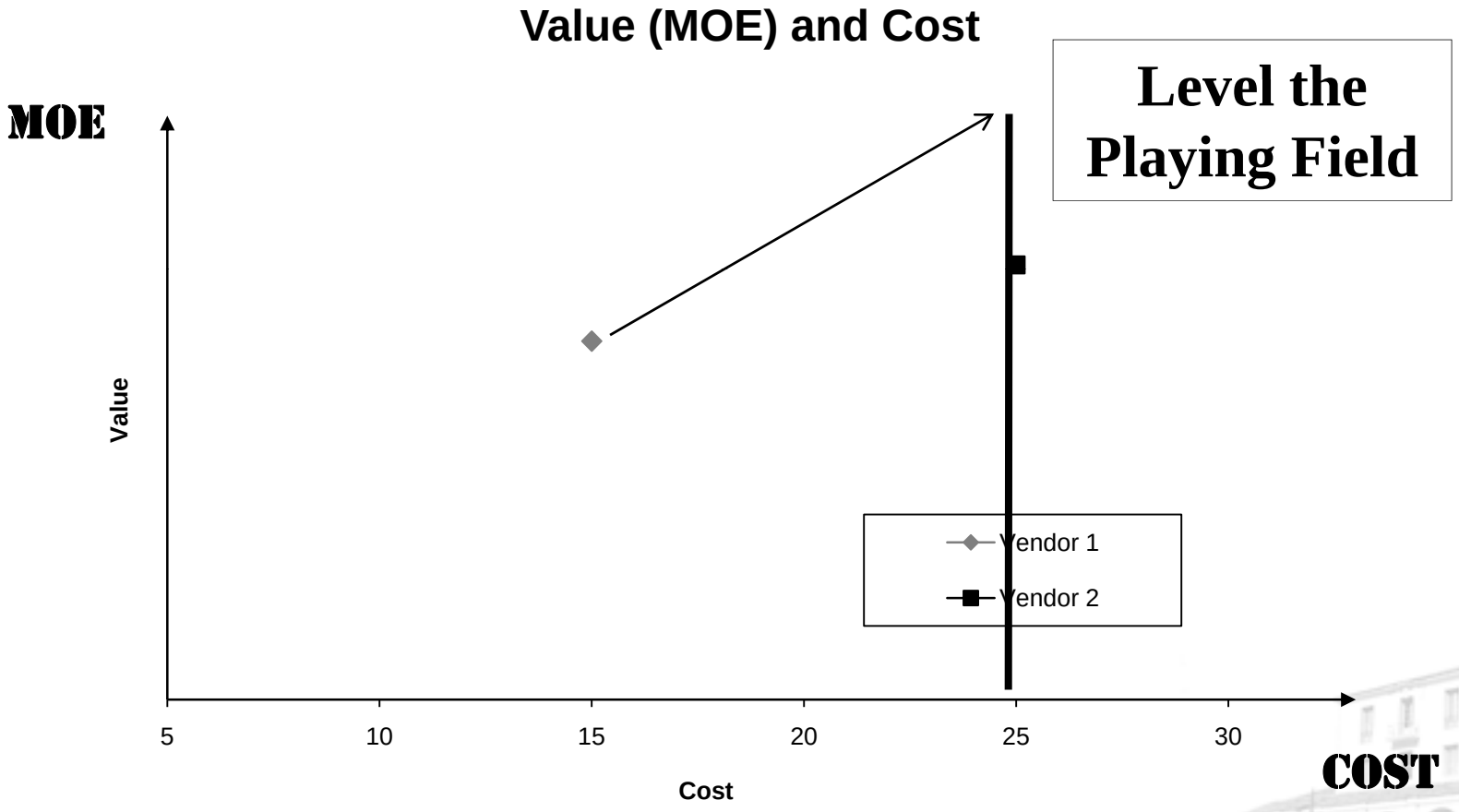
- For simplicity, analysis assumes:

  Two attributes

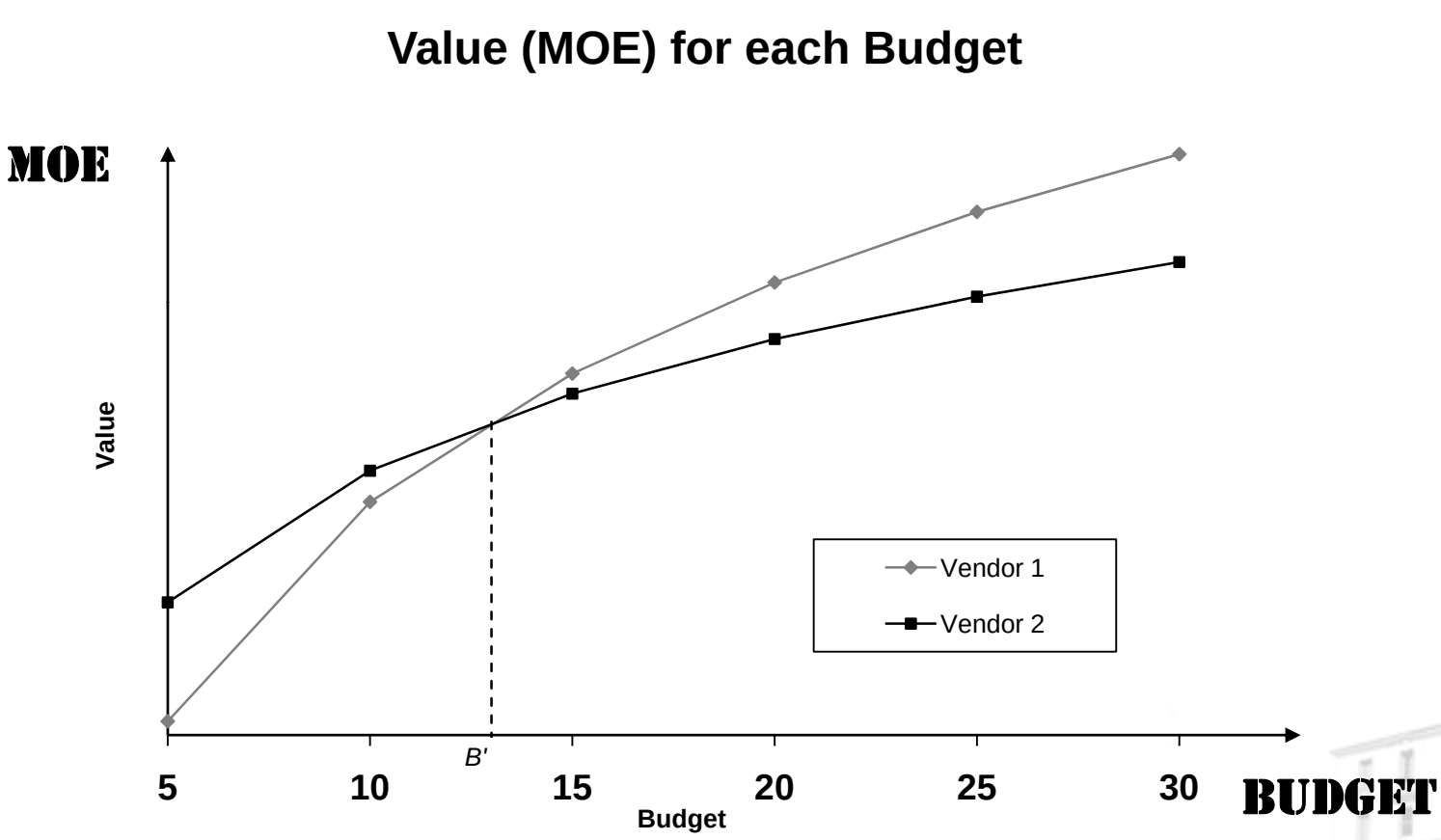
  Two vendors

- Vendors can differ in their cost functions

Traditional Price & Performance Bid



Individual Vendor Offers over a Range of Budgets



Budget Uncertainty

- Challenges:
  - Optimal vendor choice can change with changes in the budget
  - Large & rising federal debt results in shrinking discretionary defense budget

  => Increasing Budget Uncertainty

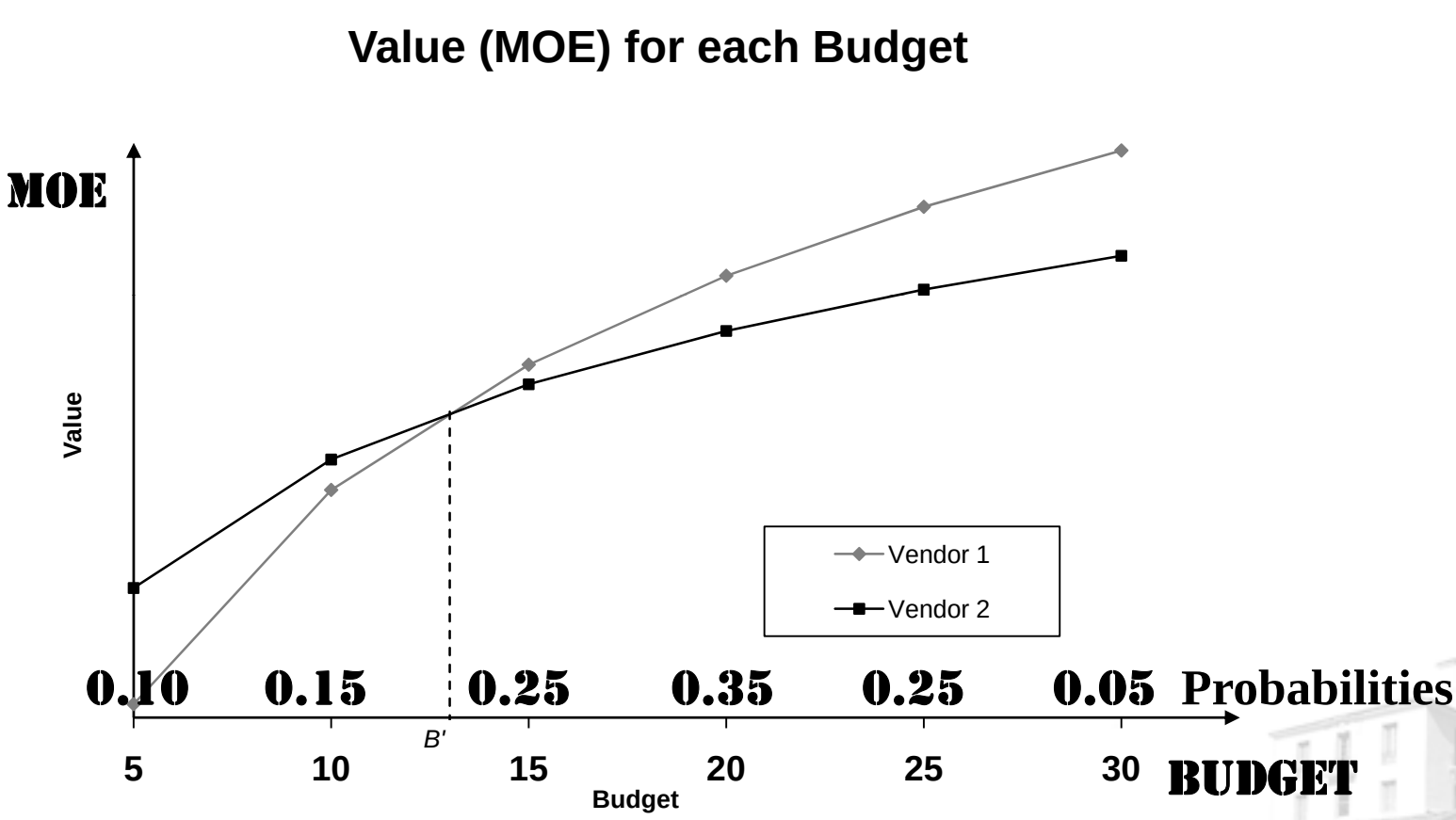
Budget Uncertainty

- If we can assign probabilities to the possible budget levels, we can use ***expected utility*** as a **vendor selection metric** for the economic evaluation of alternatives

Vendor Selection Metric (VSM)

- Vendor Selection Metric (VSM) is an expected utility function that depends on:
  a) the decision maker's beliefs of the likelihood of each budget level
  b) the relative preferences of the attributes offered, and
  c) attitude toward risk

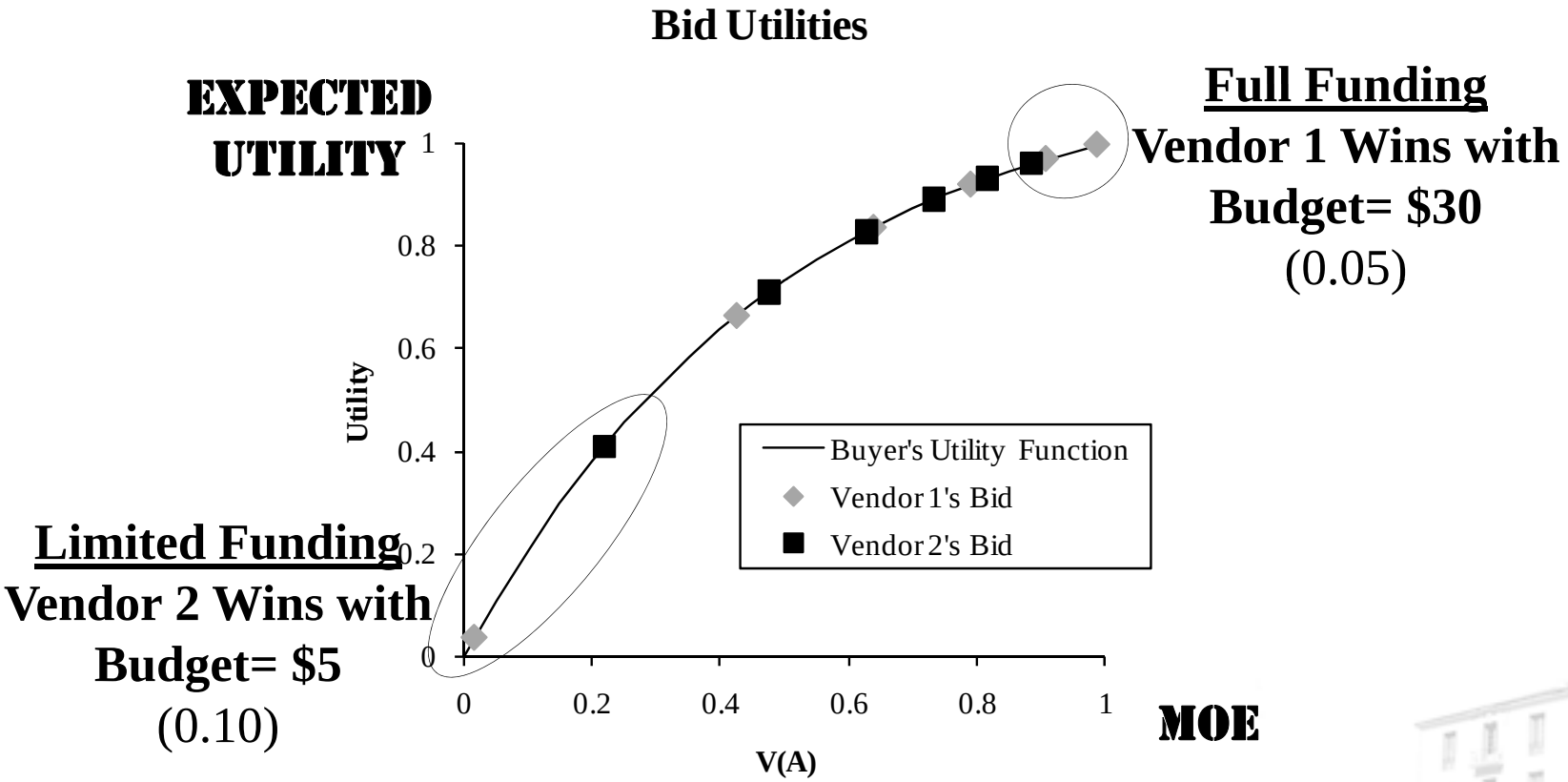
Suppose DoD believes these are the probabilities associated with each funding level



Vendor Selection Metric (VSM):

- Given these probabilities for the six budget levels and assumptions about DoD's value function and risk aversion, the vendor selection metric is:
  - **0.771 if vendor 1 is selected**
  - **0.800 if vendor 2 is selected**
- **This new metric suggests DoD should select vendor 2**

Vendor Selection Metric (VSM)



The buyer's utility function and the value and corresponding utility offered by each vendor for the six budget scenarios in the decision under uncertainty example.

Interpretation of Results:

- Dividing new vendor selection metric (VSM) into component parts provides additional insight.
- Even though Vendor 2 wins, the VSM values for each vendor are fairly close:
  - **Vendor 1 = 0.771, and Vendor 2 = 0.800**
  - However, for budget levels $15, $20, $25, and $30, the bundle of attributes provided by vendor 1 is more desirable, and there is a 75% probability one of these budget levels will be realized!
  - But there is a 10% probability of a serious budget cut to $5 in which case vendor 2 provides a substantially superior offer.

Conclusion:

- Such insights would be impossible to obtain with only a single bid from each vendor, say for the most likely budget, b = \$15, with a probability of 0.35.

- More revealing and robust analysis is only feasible if DoD solicits vendor offers over multiple budget levels and assesses the likelihood of those budgets.

Recommendations

- Allow vendors to submit bids for a range of possible funding levels
  - Full Funding=Optimistic; Partial Funding=Most Likely; Limited Funding=Pessimistic.
- Instead of viewing each vendor as a single point in cost-effectiveness space, it is important to solicit vendor offers at different levels of affordability.

Recommendations

- A vendor whose bid is dominated at one budget level could be the winner at another budget level.
- This makes it vital for procurement agencies to rethink traditional public sector bid solicitations.
- Develop expansion paths to illustrate how each vendor's offer changes with changes in funding.

Recommendations

- With increased budget uncertainty, assign a probability distribution over possible budgets (funding/affordability levels).
- Develop a **Vendor Selection Metric** (**VSM**) that captures budget uncertainty and DoD's attitude towards risk.
- Calculate **VSM** value for each set of vendor proposals and use to guide vendor selection decisions.

STOP

- **Suppose the buyer has the exponential expected utility function below where, as previously specified, *V* varies between zero and one over the possible attribute bundles. This vendor selection metric (VSM) represents a decision-maker who is risk averse.**

Note that since the minimum value of *V* is zero and the maximum is one, *U*(*V*) also varies between zero and one. We chose the exponential function because it has constant absolute risk aversion, measured by a risk tolerance parameter (in this case, 0.5), making its assessment reasonably straightforward. It is commonly used in decisions under uncertainty.

$$U(V) = \frac{1 - e^{-2V}}{1 - e^{-2}}$$

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

Solution to Vendor's Problem

- A vendor's best offer (bid) will consist of the combinations of attribute levels that use the entire possible budgets, and satisfy the condition:

$$\frac{w_{i1}}{c'_{i1}\left(v_1\left(a_{i1}\right)\right)} = \frac{w_{i2}}{c'_{i2}\left(v_2\left(a_{i2}\right)\right)}$$

- This set of offers from a vendor constitutes an "expansion path"