A Robust Framework for Analysis of Alternatives

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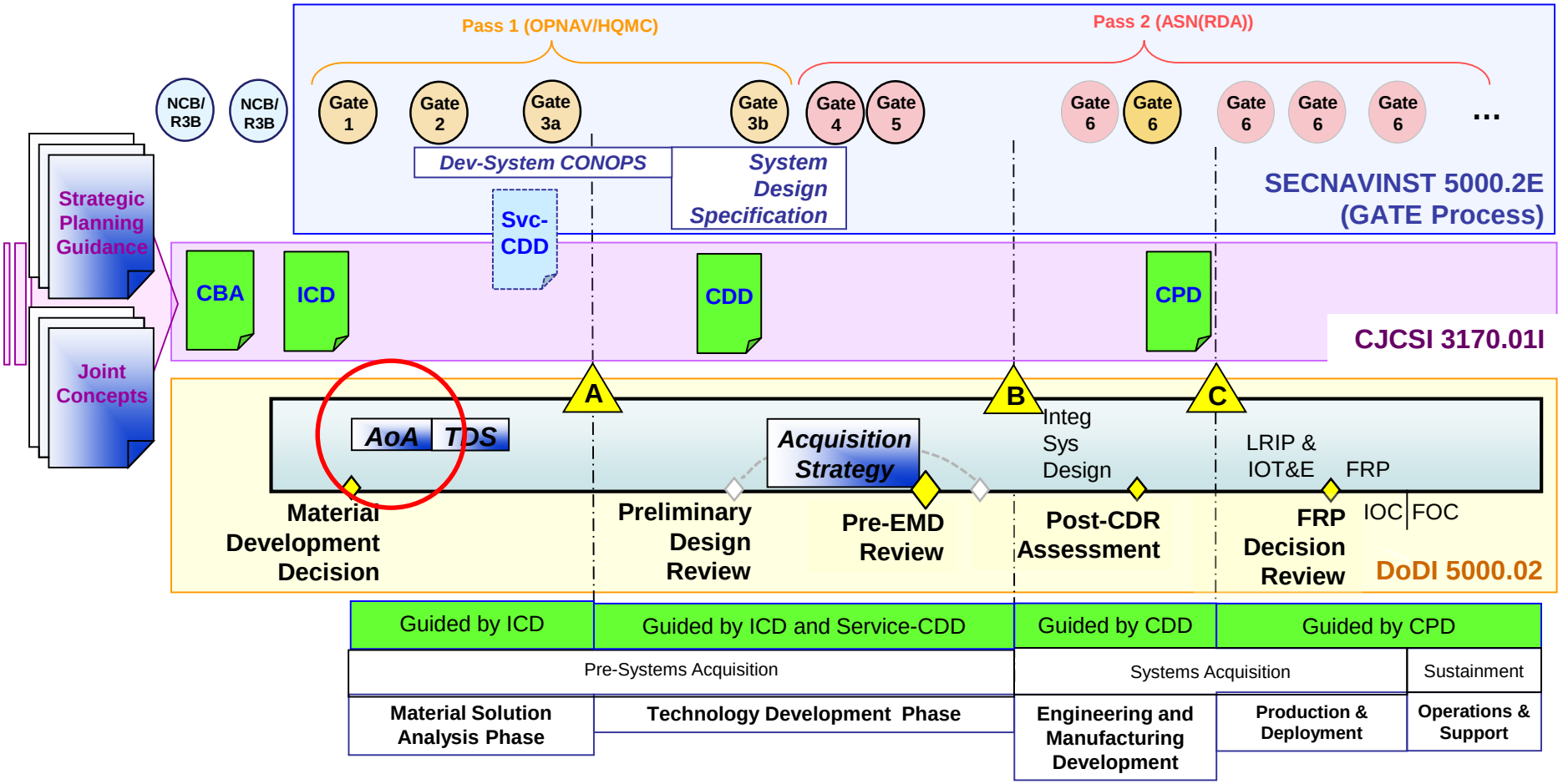
Overview

- Analysis in the Defense Acquisition System
- Problem Motivation
- Utilization of Multi-Criteria Decision Making
  - Four dimensions of AoA process: Alternatives/Criteria/Scenarios/Stakeholders
  - Criteria Tree
  - Formulation
- Summary

Big "A" Acquisition Process*



AoA – Analysis of Alternatives
CDR – Critical Design Review
FOC – Full Operational Capability
FRP – Full Rate Production
IOC – Initial Operational Capability
IOT&E – Interoperability Test & Evaluation
LRIP – Low-rate Initial Production
PDR – Preliminary Design Review
TDS – Technology Design Specification

* PPBE process not shown

Research Motivation

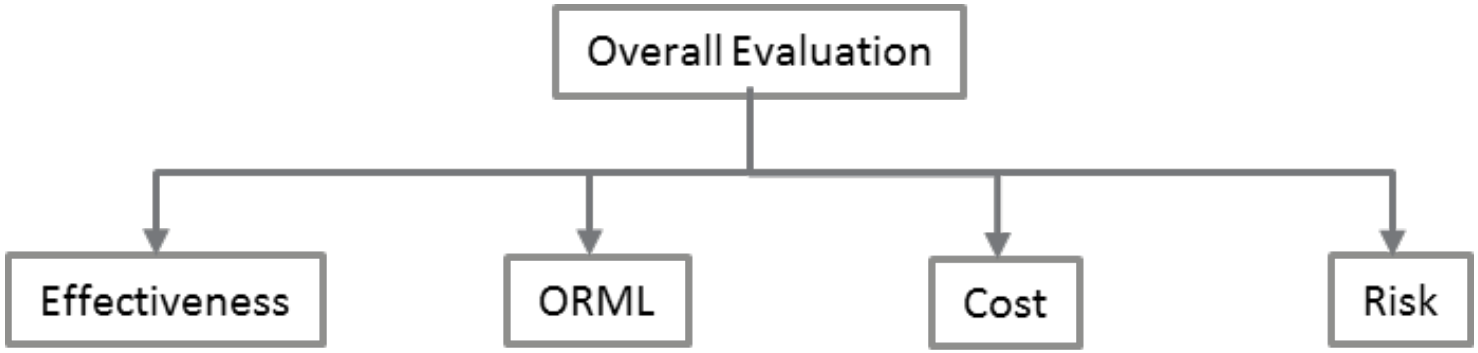
State of Practice

- Most AoAs studies lack desired structural or formal rigor
  - In-context evaluations of alternatives with respect to criteria
  - Determination of criteria weights
  - Weakness in treating uncertainty and risk
  - Inadequately aggregating preferences among stakeholders
- Analytic process ignores differing stakeholder opinions regarding importance of measurable criteria

Objective

- Develop a comprehensive formal framework for executing Analysis of Alternatives (AoA) and introduce a unified analytic structure into the process
  - Propose a clear “standard” for conducting an AoA
  - Explicitly addressing the role of scenarios and stakeholders in the AoA process
  - Develop a “distance-based” model that simultaneously addresses all four dimensions of the AoA process

Criteria Tree



- Effectiveness: determined by measures of effectiveness (MOEs)
- Operationability, reliability, maintainability, and logistics: measured by both MOEs and cost
- Cost: measured in money spent and/or to be spent
- Risk: cost, schedule, or performance; can be highly subjective

Examples:

- If the item to be selected is a tank, then sub-criteria can evolve from the Effectiveness criteria
- Clearing mines from a strait or other body of water

Formulation

Comparing the Values of the Alternatives

$$V_i^* = \sum_{j=1}^{J} w_j v_{ij} \; for \; i = 1, \ldots, I \quad (1)$$

where

$$w_j \; denotes \; the \; weight \; of \; criterion \; j$$

$$v_{ij} \; is \; the \; value \; of \; alternative \; i \; with \; respect \; to \; criterion \; j$$

Challenge:

- There is no scientific method that could provide the “true” weight of a criterion
- Different stakeholders may have different opinions regarding a certain criterion
- Criterion may be dependent on the scenario

Determining Criteria Weights

$$Given\ a\ set\ of\ R\ stakeholders\ considering\ a\ scenario\ s, we\ have\ criteria\ weights\ w_{js}\ for\ j = 1, \dots, J$$

$$We\ ask\ each\ stakeholder\ r, where\ r = 1, \dots, R\ to\ compare\ two\ criteria\ weights\ w_{js}\ and\ w_{ks}\ with\ respect\ to\ scenario\ s$$

$$The\ comparison\ is\ in\ terms\ of\ the\ ratio\ between\ the\ two\ weights$$

$$p^r_{jks}\ is\ the\ assessment\ of\ stakeholder\ r\ for\ the\ ratio\ \frac{w_{js}}{w_{ks}}$$

$$In\ general,$$

$$p^1_{jks} \neq p^2_{jks}$$

Solving for Criteria Weights

Formally, we solve the following non − linear optimization problem

$$Min \sum_{j<k} \sum_{r=1}^{R} \left(\frac{w_{js}}{w_{ks}} - p_{jks}^{r} \right)^2$$

such that

$$\sum_{j=1}^{J} w_{js} = 1, w_{js} \geq 0$$

The solution to the above problem is a vector of criteria weights for a particular scenario s; the problem is solved S times

Although the objective function is non − linear, it can easily solved using MS Excel Solver

Solving for an alternative's value is computed in a similar manner

Scenario Value Function

Thus, equation (1) can now be solved for the consensus overall value of alternative i in scenario s

$$\overline{v}_{is} = \sum_{j=1}^{J} w_{js} v_{ijs}$$

Extension of formulation

- Stakeholder assessment of relative likelihood of a particular scenario
- Differences in stakeholder influence

Summary

- Developed framework provides a robust, repeatable, and transparent methodology for ranking alternatives
- Extends to any number of stakeholders, each of who may provide different and often conflicting opinions
- Technical tool that can help facilitate discussions and guide decisions; not an "Oracle" that provides *the* "solution"
- Methodology easily implemented using widely available software, e.g. Microsoft Excel

Scenario Probabilities

Formally, we solve the following non − linear optimization problem

$$Min \sum_{j<k} \sum_{r=1}^{R} \left(\frac{q_s}{q_t} - a_{st}^r \right)^2$$

such that

$$\sum_{s=1}^{S} q_s = 1, q_s \geq 0$$

where

a_{st}^r *is the subjective opinion of stakeholder r regarding the extent scenario s is more (or less) likely than scenario t*