COST BENEFIT ANALYSIS METHODOLOGY FOR STRATEGIC INVESTMENTS IN INDUSTRIAL BASE SUPPORT

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**John V. Farr**
United States Military Academy  
Email: John.Farr@usma.edu

**Jacqueline A. Harris**
United States Military Academy  
Email: Jacqueline.Harris@usma.edu

**Gregory J. O’Conner**
Program Executive Office Ammunition, Picatinny Arsenal  
Email: gregory.j.oconnor.civ@mail.mil

Address: Center for Nation Reconstruction and Capacity Development, Department of Systems Engineering, United States Military Academy, West Point, New York 10996  
Phone Number: 845-938-5206

**Abstract**
In today’s resource-constrained environment, the Army must exercise wise stewardship of every dollar managed. A key element in our conservancy is to develop and use sound cost benefit analysis (CBA) practices throughout all requirements/resourcing processes. Supporting the industrial base is just one of the key force enablers that support not only power projection issues but the ability of the Army to perform its’ mission. The purpose of this research is to develop and articulate a CBA process specifically for investments in industrial base projects with a focus on production support for the Army ammunitions industrial base. The process will assist analysts in identifying, quantifying, and evaluating the future costs for strategic production investments. We used the Army’s CBA guide to structure our process. Our research focused on how to develop quantifiable and non-quantifiable benefits for the proposed investments which is a key step in the process. Specifically, we used value modeling with total ownership costs to develop the quantifiable benefits. We also developed a means to represent risk within a value modeling approach.

**Keywords**
Industrial Base, Value Modeling, Multi Attribute Utility, Cost Benefit Analysis

**Introduction**
The purpose of this research is to develop and articulate a cost benefit analysis (CBA) methodology specifically for investments for the government owned, contractor operated (GOCO) ammunition plant modernization strategy for the Department of the Army. This research will assist Army analysts and agencies in preparing a CBA to support Army decision-makers in funding product modernization, safety, and environmental capital projects in support of the Army ammunitions program (AAP) industrial base.

The U.S. Army currently owns five government owned and government operated (GOGO) arsenals and ammunition plants and six GOCO ammunition plants. Although these facilities increased production to support recent operations in Iraq and Afghanistan, they are currently facing declining workload and under existing business rules and will likely have to raise their prices to cover the costs of underutilized capacity (Karishma, 2013). At the
GOCO sites production is decreasing with a 50% reduction in funding since a FY2006 high of $3.2B (Karishma, 2013). Many of these plants were established during World War II and about 50% of the industrial base closed as part of the 2011 Base Realignment and Closure. Thus, with reduced redundancy, old equipment, increased environmental and safety requirements, etc., the Army must strategically plan to invest in modernization of these important operations.

The research conducted was to develop a CBA methodology for prioritizing the hundreds of modernization projects proposed annually by the existing six GOCOs. The proposed methodology is based upon current Army policy (U.S. Army, 2012a). The mathematics of conducting cost analysis are well known. However, this research focused on quantifying the value of proposed projects.

Thus, the key objective of this research was to develop a means to conduct defensible, quantifiable, and transparent analysis that could assist to

- increase manufacturing readiness to meet current and future requirements,
- improve safety and environmental compliance,
- reduce Army ammunition plant (AAP) operating costs and footprint,
- improve quality and efficiency, and
- improve the quality of the work environment.

Our approach was based upon the requirements to

- identify, consolidate and prioritize production deficiencies, aligning with Department of Defense (DoD) needs,
- develop 1 to N priority list scoring criteria driven by operational continuity and quality, environment, safety, and financial benefits,
- be aligned with strategic modernization initiatives,
- target organic capabilities and required capacities not found in the commercial sector, and
- ensure that we characterize and account for "critical" requirements.

In today’s resource-constrained environment, the Army must exercise wise stewardship of every dollar it manages. A key element is to develop and use sound CBA practices throughout all requirement/resourcing processes. For every proposed program, initiative or decision point that will be presented to decision-makers, it is important to provide an accurate and complete picture of both the costs estimates and the benefits to be derived.

Overview of CBA
A CBA provides decision-makers with facts, data, and analysis required to make an informed decision. Specifically, a CBA is a decision support tool that documents the predicted effect of actions under consideration to solve a problem or take advantage of an opportunity. A CBA defines a solution aimed at achieving specific Army and organizational objectives by quantifying the potential financial impacts and other business benefits such as:

- Savings and/or cost avoidance,
- Revenue enhancements and/or cash-flow improvements,
- Performance improvements, and
- Reduction or elimination of a capability gap

The biggest challenge in the CBA process is to consider all benefits to include non-financial or difficult to quantify benefits of a specific course of action (COA) or alternative.

These eight-steps of the Army CBA process are graphically depicted in Exhibit 1.

Literature Review
A wealth of literature exists on the needs to sustain and modernize the defense industrial base (see Watts and Harrison, 2011, U.S. Army, 2012b, and Watts, 2012). Hix et al (2004) published a review of how Canada outsourced its ammunition manufacturing. Rand also published several reports on the various governance models for the GOGOs and GOCOs. However, little exists in presenting methodologies to strategically invest in plant modernization. Farr and Prakel (2013) developed a methodology similar to the process used in this paper for energy security upgrades at military facilities. Alsfelder, et al (2012) used a multi objective decision analysis (MODA) very similar to the value focused thinking methodology used herein and data envelopment analysis (DEA) to evaluate value as a function of life cycle costs of different energy security measures and renewable energy for military installations.
Eight Steps in the CBA Process

Step 1 - Problem or Opportunity Statement
The first and one of the most important steps in the CBA process is to develop the correct problem/opportunity statement. A problem statement clearly defines the problem, mission need, and required capability. An opportunity statement is similar to a problem statement, but is focused on taking advantage of a favorable situation. This helps to ensure that the CBA is meeting the needs and requirements (which will be covered later in this step) of the stakeholders. This is accomplished by soliciting stakeholder input as a data source at key points.

Step 2 - Scope
The scope of the analysis defines the range of coverage encompassed by the project along specific dimensions such as time, location, organization, technology or function. The CBA should state the involved stakeholders, period of time that the analysis covers, as well as organizations or requirements not covered or addressed in the analysis. Defining the scope of the CBA is critical because it keeps the CBA focused on the things that matter.

Step 3 - Define Alternatives
It is imperative that the CBA prepares unbiased solutions or monetary valuations for the decision maker, based on critical reasoning and reliable information (data). Alternatives can be intuitively obvious to the analyst or team preparing the CBA or they may take a determined effort to define. For our problem these projects are often developed by the contractors operating the facility. Thus, the contractors often have a short-term bias towards reducing costs or improving reliability.

Cost analysis is a critical element in the CBA process. Total ownership cost (TOC) estimates support management decisions by translating resource requirements (e.g., equipment and personnel) associated with programs, projects, or processes, into dollar values. It is one of the most challenging steps in the CBA process as much of the analyst’s time is spent on obtaining data. Using the best data available will result in the best estimate. Finally, it is important to capture all the costs related to the initiative or project for which the CBA is developed.

Step 5 - Identify Quantifiable and Difficult to Quantify Benefits
Benefits of a chosen alternative are results expected in return for costs incurred. They are the quantitative and qualitative results expected or resulting from the implementation of a project/initiative (which may include but are not limited to the following: equipment, facilities, hardware, systems, material, labor, etc.).

When preparing a CBA, identify all direct and indirect benefits to justify the costs identified in the CBA. Both financial benefits (i.e., those measured in dollars) and non-financial or functional benefits require establishment. Both are essential to the analysis and selection of a preferred COA. Each benefit must be clearly and distinctly identifiable, and should not duplicate any other measure. Quantifiable benefits have numeric values such as dollars, physical count of tangible items, or percentage change. Difficult to quantify benefits, in most cases, can become quantifiable with an appropriate measuring/counting methodology.
Step 6 - Define Alternative Selection Criteria
Alternative selection criteria are the standards used to rank the alternatives in order of preference, and to identify the most advantageous course of action/alternative. After collecting and analyzing data for the proposed alternatives, and completing cost estimates, the decision criteria for selecting the “preferred” alternative must be determined. In many cases, the total cost or primary benefits are part of the selection criteria. A CBA must contain documentation that defines decision criteria and its impact in making the recommendation of the preferred alternative. It is important to customize the criteria to the CBA. Note that advanced analysis techniques such as DEA (used to evaluate the efficiency of a number of producers) could be used for assessing the relative effectiveness of an alternative based upon multiple criteria.

Step 7 - Define Alternative Selection Criteria
The essence of the CBA process is comparing the costs and benefits of two or more alternatives (including the status quo) in order to select the preferred alternative. As a general rule, the preferred alternative is the one that provides the greatest reward in relation to its cost. In situations where it is difficult to quantify benefits and measures of effectiveness, it is important to provide as much useful information as possible to support a decision as to which alternative yields the most benefits, or offers the greatest value.

Step 8 - Compare Alternatives
As noted above, financial and non-financial criteria must be captured in some value measure. The decision maker needs to be informed about how well the alternative’s rankings will hold up under reasonable changes to factors and assumptions. Ideally, an analyst can answer questions such as “Which variables are important in this problem?”, “What is the threshold of this variable?”, or “If this variable changes by some amount, does the optimal choice change?”, following sensitivity analysis. Because solutions rely on the assumption that input parameters are constant, sensitivity analysis determines how sensitive solution are to these parameter changes.

Step 9 - Report Results and Recommendations
CBA documentation should describe the functional process performed, define the requirement, and identify significant assumptions, constraints, and key variables. The CBA documentation should also identify feasible alternatives, and present total costs and differential savings expected in constant, discounted, and current dollars over the project life. The CBA must address estimating methods/relationships and data sources, treat sensitivity, risk, and uncertainty of key cost drivers and assumptions, and address all quantifiable benefits as well as any difficult to quantify benefits influencing the recommended course of action.

Investing in the Army Ammo Industrial Base
Exhibit 2 is a systemigram of the industrial base for Army ammunition production. Systemigrams provided a model demonstrating interdependencies between variables via the usage of action words on arcs. They provide value in visualizing complex problems.

As previously discussed, the economics of developing TOC costs are well understood but often not followed. Thus, for the example problem we chose to focus on how to develop quantifiable and non-quantifiable benefits (Step 5). In reality we converted all benefits to either a quantitative or qualitative measure. We used value modeling to quantify and rank alternatives with the objective of selecting a preferred alternative. It is useful in enhancing decision making for allocation of resources and solidifying support for a particular portfolio of projects. Value modeling is used to assist in selection of a preferred alternative and is useful in enhancing decision making for a particular portfolio of alternatives technologies.
Exhibit 2. Systemigram demonstrating second and third order effects of investing in the industrial base

Multi objective decision or value analysis (Kirkwood, 1996) uses an overall value function that combines the multiple evaluation measures into a single measure of the overall value of each evaluation alternative, or portfolio of projects. Thus, a comparison of different mixes of alternatives in a portfolio is possible in determining the appropriate mix for maximizing value. The value modeling methods are based upon developing structured objectives, evaluation measures, value functions, and subsequently, assigning weights. The process of developing a value model begins with the development of value hierarchy structure enlisting the objectives, functions and measurement metrics of the functions. Depending on the complexity of the value hierarchy model, the functions and their measurement metrics can be further broken up into subsequent layers. Exhibit 3 shows the value hierarchy for our problem.

When using value modeling, a structured approach must be taken to develop the weights, objectives, and functions. In this paper, the authors present objectives and functions based upon the experience of the authors, literature, and input from subject matter experts.

Ideally, all stakeholders should be involved at all levels in the development of values and weights. In general, there is often very little disagreement on the objectives, functions, and how to quantify the functions. However, stakeholder interests are especially important and often controversial when assigning the weights. For example, one group of stakeholders might place a higher value upon existing market maturity versus innovation of the new product. Stakeholder buy-in is critical with all parties agreeing to the proposed framework. Sensitivity analysis can play a key role here to show how varying the weights over different ranges can have minor or major impact on the objective function. Exhibit 4 contains a generic matrix of the range of variation of the value measures versus importance. The numbers in parenthesis in that table represent the weights we assigned to the swing weight matrix and are based upon the research by (Parnell and Trainor, 2009).
A multiple criteria value function based upon weights and scores assists to rank alternatives. An additive value function is used for this research since it is common. The additive multi criteria function $V(a_i)$ is shown in Equation 1.

$$V(a_i) = \sum_{k=1}^{m} W_k V_k(a_i)$$  \hspace{4cm} (1)$$

where $$\sum_{k=1}^{m} W_k = 1$$ and $0 \leq v_k(a_i) \leq 10$ for all $k = 1, \ldots, M$.

The quantity $v_k(a_i)$ is the assessed value of the portfolio $a_i$. The weights $W_k$ represent the tradeoffs across the criteria (weight and values). A portfolio of candidate technologies is constructed and defined $P = \{p_1, \ldots, p_n\}$.
When weights have been determined for the current situation, the model is useful in identifying the technology or mix of technologies that have the highest potential to be disruptive in the marketplace. We can then view projects as a function of cost or some other variable to make logical and defendable investment decisions.

Exhibit 5 contains the value measures used for our problem. Note two important characteristics. First, cost is not included as a value measure. It is not an input variable. Instead, cost is used as a means to compare the value of various projects. Exhibit 6 contains a simple plot of value versus cost. We could also plot cumulative cost versus value, percent cost as a function of value, etc. These types of plots should be used not so much to prioritize projects but to gain insight into what projects provide the biggest value for the investment. Further investigation, discussions with stakeholders, etc., is useful to prioritize order projects for funding. This is simply the first step.

Secondly, note from Exhibit 5 that we have assigned higher value measures for mitigation measures for safety and environmental projects. For example, a project might address a safety issue that has a small probability of occurrence yet could produce significant results. By using this type of methodology we have built risk into our value measures.

Summary and Conclusions
We have presented a CBA analysis designed for investing in modernization projects to support the Army manufacturing enterprise that is guidance based (U.S. Army, 2012a). The CBA guidance uses a combination of well-understood engineering, economic and decision analysis techniques. However, quantifying the value of important modernization projects continues to be a challenge. We have presented a very simple methodology to quantifying the value using value-modeling techniques. Other techniques can also be used such as DEA. Using the methodology detailed throughout the paper, we have developed a detailed example, which can be seen in exhibit 5 and 6, of how to not only justify but also prioritize investments in energy security projects.

References


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Keeney, Ralph L., Value Focused Thinking, Harvard University Press, Cambridge, Massachusetts, 1992


Exhibit 5. Weights and value for modernization projects for the ammunition industrial base

- **Energy Security and Consumption**
  - Global Weight: 50
  - Importance of Value Measure: 9%
  - Value Measure: Increases Energy Consumption and/or Reduces Security
    - Neutral: 0
    - Contributes: 50
    - Mitigates: 100

- **Safety**
  - Global Weight: 60
  - Importance of Value Measure: 11%
  - Value Measure: Probability of Occurrence
    - Minor Injury: 20
    - Lost Time: 60
    - Death or Major Disability: 100

- **Environmental Considerations**
  - Global Weight: 50
  - Importance of Value Measure: 9%
  - Value Measure: Probability of Occurrence
    - Minor Envir Impact: 20
    - Environ Issue: 60
    - Major Environ Concern: 100

- **Quality**
  - Global Weight: 100
  - Importance of Value Measure: 19%
  - Value Measure: Decreases or No Effect on Quality
    - Neutral: 0
    - Minor Increase: 20
    - Significant Increase: 40
    - Major Increase: 100

- **Production Capacity/Throughput**
  - Global Weight: 100
  - Importance of Value Measure: 19%
  - Value Measure: Decreases or No Effect on Productivity
    - Neutral: 0
    - Minor Increase: 20
    - Significant Increase: 40
    - Major Increase: 100

- **Reliability/Resiliency**
  - Global Weight: 100
  - Importance of Value Measure: 19%
  - Value Measure: Not A Strategic Investment Project
    - Limited Strategic Value: 0
    - Important Strategic Value: 100

- **Strategic Project**
  - Global Weight: 80
  - Importance of Value Measure: 14%
  - Value Measure: Not A Strategic Investment Project
    - Limited Strategic Value: 0
    - Important Strategic Value: 100
Exhibit 6. Plot of initial investment, TOC, and cumulative costs versus value for representative modernization investments