Defence Investment Prioritization

John A. Steele
Defence R&D Canada – Centre for Operational Research & Analysis
NDHQ Carling Campus
CANADA

John.Steele2@forces.gc.ca

ABSTRACT

At the strategic level, the principal "Challenge for NATO OR&A in a Changing Global Security Environment" concerns how to affordably optimize the capabilities embodied by fielded military forces to meet national and alliance requirements to address that changing security environment. After systematic comparison of expected future requirements to the force being delivered, a series of candidate capability investment trade-offs are needed, informed by budget, cost and risk. Getting those trade-offs right is the defence planned investment portfolio problem. This paper outlines what the literature describes as best practice for defence investment prioritization and reports ongoing work within SAS-134 to illustrate instances from NATO and partner nations touching on portfolio objectives formulation, value modelling and the socio-technical process of investment prioritization and planning.

1.0 INTRODUCTION

Investments in defence are among the most complex that any nation makes, due to the array of risks they face: promising to exploit still-maturing bleeding-edge technology, taking longer to deliver than promised, costing much more than estimated when funds were allocated or being considered no longer affordable in an economic downturn. The scale of their costs and distribution of regional industrial benefits often make them the focus of partisan public scrutiny, subjecting them to amendments with more political than military utility. The aggregation of these effects over an entire national defence investment portfolio makes the resulting trajectory of military capability evolution very difficult to predict and manage. The changing global security environment only adds to this complexity by obscuring the best and most robust aim point for such a portfolio.

This paper gives a very brief overview of the literature on best practice for defence investment prioritization as surveyed by SAS-134 "Linking Strategic Investment & Divestment to Defence Outcomes", a research task group of six nations seeking to define and illustrate best practice in defence investment prioritization. The origins of the group are in the author's work on modelling capital investment value from 2014-2016, supporting a transition in the way Canada's Department of National Defence plans its long-term capital investments, and a desire to expose that work to and learn from other nations through the NATO Science and Technology Organization (STO). This paper concludes by soliciting participation in a survey we have developed of national defence investment prioritization practice.

In the rest of this section, we present the main features of the problem and outline the rest of the paper.

1.1 Problem

When military service chiefs are asked for their capability development priorities, they readily list investments needed to win against threats and hazards they expect in the future. Taken together, their estimated costs and those of the other enabling organizations of National Defence (ND) typically exceed forecast defence investment budgets. The challenge is to select from this combined set of interlinked and sometimes notionally-priced investments a subset that will:

- deliver the capital assets most needed to deter or defeat future national and alliance threats;

- be affordable against uncertain future allocations for ND investments; and
- gain the agreed support of all major stakeholders within ND, central government agencies and the government of the day.[1]

We will not address the capability assessment stage, to which NATO SAS has already given much attention. We assume that ND capability planners have evaluated the trajectories of their current capability sets over time given the delivery schedules of investments already underway, and assessed them in combination against anticipated threats and hazards to identify and prioritize capability gaps, but have not yet considered costs or resource constraints.[2]

1.2 Outline

In §2, we briefly describe the literature touching defence portfolio planning. In §3, we summarize the elements of best practice from the literature. Section 4 concludes and describes an ongoing SAS survey of national portfolio planning practices.

2.0 TYPES OF LITERATURE

Principal contributions to solving the defence investment portfolio planning problem come from three broad sources summarized below, principally from Tate & Thompson [1].

2.1 Financial

The financial portfolio literature shows that money is worth more sooner than later, which is why we apply discount rates on investment costs and returns over time. Modern Portfolio Theory integrates investment risks and returns, linking them through return covariances and allowing investors to set portfolio goals in terms of both risks and returns. More recently, Real Options Analysis provides a framework for the active investor to exploit the information value of delayed decisions at the cost of preliminary spending to keep other investment opportunities open as the future unfolds.

2.2 Operations Research

The Operations Research (OR) literature has tended to focus on computational challenges, defining itself by classic problems, better algorithms and tractable heuristics, given the necessary data. Hence, portfolio analysis has often involved investments of known duration, known cost, simply modelled benefit and only sequential dependency; available money and other required resources over time constrain the portfolio; and the objective function to be optimized is a sum of modelled investment benefits. See [2] for a concise compilation of defence capital planning variants.

Portfolio quality measures in OR have tended to be rudimentary, but simple objective functions can be misleading when addressing long-term strategic decisions with multiple stakeholders, conflicting objectives and deep uncertainty in threats to be countered, future capability effectiveness delivered, future government allocations and final capability costs.

2.3 Decision Analysis

The Decision Analysis (DA) literature prescribes formal decision structures that manage just these types of decision complexity [1]. The DA approach models the decision frame (including decision scope and motivation), decision objectives and their relative priority, specific decision alternatives, how alternatives

[1] A full articulation of the intrinsic complexities of the defence investment portfolio problem is found in §1 of [1].

[2] For smaller nations, the bulk of this analysis may have been provided by the NATO Defence Planning Process.

further those objectives and the implications for preferred choices. Figure 1 shows the essential elements of Decision Analysis according to Howard [3].

When expected decision outcomes cannot be monetized, the most powerful structures for working out their implications are underpinned by multi-attribute value and utility theories (MAVT and MAUT) [4], which provide quantitative tools for handling and maximizing decision benefit when decision outcomes are and are not certain, respectively. Less restrictive and less powerful decision foundations are laid in the French "Decision Aid" school with Outranking methods [5], in the Analytic Hierarchy Process of Saaty [6][7] and non-compensatory methods, when trade-offs between decision criteria cannot be identified [8]. These constitute the best known approaches within the multi-criteria decision analysis (MCDA)[3] domain.

3.0 BEST PRACTICE: PORTFOLIO DECISION ANALYSIS

Decision Analysis systematically addresses all six decision dimensions shown in Figure 1. Together, they span Decision Quality (DQ), which is "the correctness of the decision when it was made." Decision makers (DMs) have no control over the external circumstances driving uncertainty, so DQ is fully defined before that uncertainty bears on the outcome. It is about giving precisely the attention that is profitable to each dimension, including an appropriate decision frame or set-up; creative and doable alternatives; meaningful and reliable information; clear values and trade-offs; logically correct reasoning; and commitment to follow-through. Ultimate decision quality is defined by the least appropriately handled decision dimension. the quality of decision is which is no stronger than its weakest link.

The best practice elements offered here are mostly from [1] and from Chapman Burk & Parnell [9].

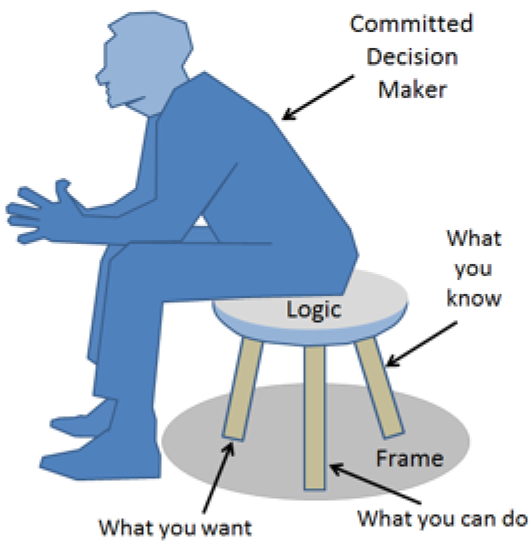

Figure 1: Essential decision elements from [3].

3.1 Frame the decision

Framing the decision means specifying the scope of the problem, defining what the portfolio can and cannot include, and ensuring you are engaging the necessary stakeholders with a decision process capable of generating a sufficiently shared commitment to implement the decision taken. One such process is Spetzler's Dialogue Decision Process (DDP) [10] that enables organizations with a DA culture and in-house DA capability to converge on a supported decision. In DDP, a trained decision board directs the definition of decision elements and ultimately decides after sequential engagement with an analysis team that gathers needed information, develops alternatives and assesses the merit of the decision options as shown in Figure 2. Alternatively, Decision Conferencing [11] involves a series of focussed meetings attended by all key stakeholders, professionally facilitated and software-supported to generate broad acceptance of a balanced solution to a complex set of related challenges.

3.2 Define portfolio success

After framing the decision, we must formally identify what we want: the outcome objectives to be achieved by the portfolio of investments, including any requirements for balance between programs. Fundamental

[3] Other names for this include multi-objective decision analysis (MODA) and multi-criteria decision making (MCDM).

objectives (FOs) matter intrinsically and break down into sub-objectives (SOs). Means objectives (MOs) matter because they serve FOs, SOs or other MOs. To the extent possible, objectives should be:

- Operational, using concepts meaningful to decision makers (DMs) and stakeholders and measurable with data that can be collected or generated in practical terms;
- Comprehensive in aggregate, touching every reason for choosing one investment over another;

Decision Board	Deliverables	**Analysis Team**
0. DESIGN process	Well defined process Set up for success →	**1. ASSESS** Business Situation
Refine focus	← Frame → ← Challenges → ← Understanding →	**2. DEVELOP** alternatives, information, values
Agree to alternatives	← Alternatives ← Improved info → ← Values →	**3. EVALUATE** alternative risks & returns
4. DECIDE among alternatives	← Evaluated alternatives Decision →	**5. PLAN** for action
Approve plan & budget	← Plan →	**6. IMPLEMENT** decisions & manage transition

Figure 2: Dialogue decision process after [10]

- As non-redundant as possible, to eliminate double counting in value modelling;
- Decomposable into measurable sub-objective layers; and
- Minimal, no more in number than necessary for defining significant types of value. [4]

When properly structured, FOs decompose to multiple measureable SOs, clarifying stakeholder intent and priorities, supporting a sound value model and a portfolio more easily explained to higher authorities in ND, central agencies and government as illustrated in Figure 3. Well-structured objectives only emerge iteratively as elaboration brings clarity. Keeney [12] provides strong guidance for objective structuring and refinement in Chapters 3 and 6.

3.3 Identify and characterize investment options

Identify the full range of investment options. A key asset for this stage is an established ND-wide common project management infrastructure that is both amenable to developing and refining new initiatives, and authoritative for project gate decision reference. Lacking this, IO collation requires care, time and luck to discover all sub-organizational IO information compartments, and to extract known future funding demands.

Keeney [12] recommends, once the objectives structure has matured, considering FOs singly or in pairs and imagining investments that would achieve only them. This exploits the learning from having evolved the objectives and can uncover organizational blind spots to yield worthy but overlooked investment options. [13]

3.4 Measure success against objectives

Metrics are needed to quantify success at the bottom of each descending branch of the objectives hierarchy. Metrics should track the extent of sub-objective fulfilment. Directly observable metrics may support benefit tracking as investment decisions are implemented, which is ideal. When no natural metric applies, proxy measures might be needed. For example, a proxy measure for "lives saved" might be a measure of the strength of life-saving protective mechanisms against lethal effects. Metrics may also need construction. Examples include Quality Adjusted Life Years in public health and Net Present Value in accounting.

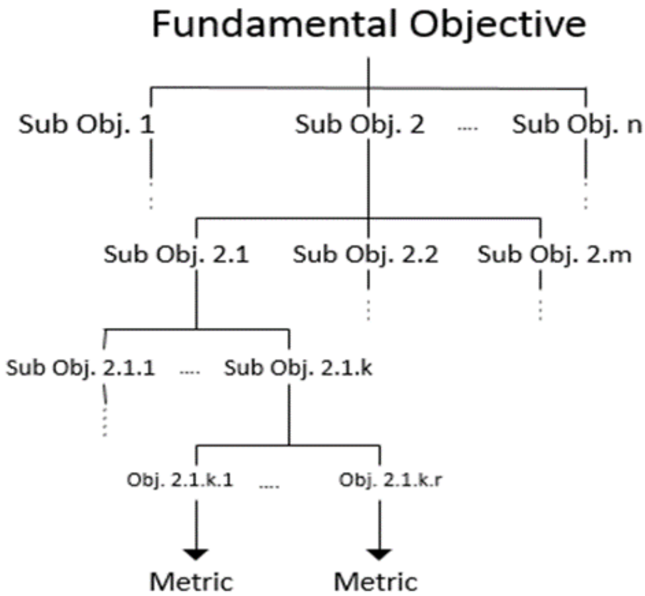

Figure 3: An objectives hierarchy under one Fundamental Objective with metrics

3.5 Translate metric scores into value levels

Metric scores must be translated into value that stakeholders recognize. Value functions are elicited with questions like "At what point between lowest and highest metric value is half the total value from this metric realized?" Some metrics indicate most of their value in their initial rise, others only in their final approach to a maximum value and others suddenly in the middle. In some cases, value is the result of more than one metric in combination. See [4] for a complete treatment.

3.6 Combine value types with swing weights

The value from satisfying each sub-objective can be aggregated and a portfolio optimization strategy used. (Optimization is faster and easier with a weighted-sum value model, but MAVT/MAUT stipulates when this is valid. The DM may need to trade-off value fidelity against optimization speed.) Determine the weights to use through a series of stakeholder judgements answering questions like: "How much of the more preferred value type would you be willing to trade away for a full-range improvement in the less preferred value type?" Proceeding systematically and checking consistency enables valid weight selection. The discovery of better objectives and metrics through this process is common.

3.7 Account for investment interactions

Some investments cannot start until others reach a certain stage, constraining investment timing. Some investments only deliver full value if other investments also execute. Some investments deliver materiel for similar (that is, partially substitutable) capabilities, so that their combined value is less than the sum of their individual values. Others are synergistic, delivering more value together than the sum of what each delivers alone. To preserve the basis for an additive value model, these interactions require special value treatment, for example, by defining new IOs as specific combinations of interacting original IOs.

3.8 Assess risk and uncertainty

While MAUT [4] gives a protocol for assessing uncertain outcomes by eliciting DM judgements of preference between lotteries, they are more demanding on DMs, do not capture intrinsic asymmetries between the way stakeholders view gains and losses, and cannot model portfolio affordability uncertainty. Most DMs prefer to use risk metrics alongside benefit metrics, for separate risk aggregation. Common risk metrics estimate the probability of realized capability, costs, schedules, or budgets exceeding some threshold value.

4.0 CONCLUSION: LITERATURE VERSUS NATIONAL PRACTICE

National law and culture can constrain decision practice, giving rise to best feasible practice. SAS-134, entitled "Linking Investments & Divestments to Defence Outcomes," is surveying international practice in defence investment prioritization, and is looking for national expert participants in this survey: people who make or analytically support their own nation's investment trade-off decisions. Readers who do this work, or work with or for others who do are encouraged to contact the author. We are collecting survey data now, and will have begun analysis of collected data by the end of 2019.

REFERENCES

[1] Tate & Thompson (2016), "Portfolio Selection and Resource Allocation for Defence Applications," Institute for Defence Analyses, IDA Document NS D-5439, March 2016.

[2] Brown, Gerald G., Dell, Robert F. and Newman, Alexandra M. (2004), "Optimizing Military Capital Planning," *Interfaces* 34(6): November-December 2004, pp. 415-425. http://faculty.nps.edu/gbrown/docs/optimizingmilitarycapitalplanning.pdf

[3] Howard, Ronald A. (2007), "The Foundations of Decision Analysis Revisited" in *Advances in Decision Analysis*, Edwards, Miles and von Winterfeldt eds., Cambridge University Press, New York.

[4] Keeney, Ralph L. and Raifa, Howard (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. John Wiley & Sons, New York.

[5] Roy, Bernard and Vanderpooten, Daniel (1996). "The European School of MCDA: Emergence, Basic Features and Current Works." *The Journal of Multi-Criteria Decision Analysis* 5, No. 1 (March 1996): 22-37.

[6] Saaty, T.L. (1980), *The Analytic Hierarchy Process*, McGraw-Hill, New York, 1980.

[7] Dyer, James S., "Remarks on the Analytic Hierarchy Process," *Management Science* 36, No. 3 (March 1990).

[8] Yoon, K. Paul, and Hwang, Ching-Lai (1995), *Multiple Attribute Decision Making*: *An Introduction*, Sage Publications, Thousand Oaks, CA.

[9] Burk, Roger Chapman & Parnell, Gregory S. (2011), "Portfolio Decision Analysis – Lessons from Military Applications" in *Portfolio Decision Analysis: Improved Methods for Resource Allocation*, Salo, Keisler & Morton eds., Springer, New York. https://www.researchgate.net/publication/226378345_Portfolio_Decision_Analysis_Lessons_from_Military_Applications

[10] Spetzler, Carl S. (2007), "Building Decision Competency in Organizations" in *Advances in Decision Analysis*, Edwards, Miles & von Winterfeldt eds., Cambridge University Press, Cambridge, UK.

[11] Phillips, Lawrence D. (2007), "Decision Conferencing" in *Advances in Decision Analysis*, Edwards, Miles & von Winterfeldt eds., Cambridge University Press, Cambridge, UK.

[12] Keeney, Ralph L. (1992), *Value-Focused Thinking: A Path to Creative Decisionmaking*, Harvard University Press, Cambridge, Massachusetts.

[13] Richter, Anke. (2019), Personnal communication.