Abstract

The Canadian Coastguard (CCG) is currently undertaking the largest re-capitalization of its vessel fleet in a generation as part of the Canadian National Shipbuilding Strategy (NSS). This re-capitalization is underpinned by a Fleet Renewal Program which was largely a ‘one-for-one’ ship replacement strategy. To ensure that the CCG remained fit for purpose into the latter half of the century, it was imperative that due consideration was applied to the development of a new Fleet Renewal Program in 2017 (FRP2017).

The FRP2017 set out to optimise the future CCG fleet composition, and shape it to ensure that the CCG can continue to conduct operations in each region and to deliver mandated services effectively and efficiently. A program of analysis has been undertaken by QinetiQ to assess a range of candidate fleet mix options in order to inform the FRP2017 decision-making process in formulating the optimum structure for the future CCG fleet.

This paper will describe the modelling of the capability to be delivered by the proposed options as well as the associated total cost of ownership (TCO). This allowed a cost effectiveness comparison of the options to be carried out.

Keywords: coast guard, cost model, Fleet Renewal Program, FRP.

Introduction

This paper will describe how QinetiQ’s operational research and cost estimating staff provided support to the Canadian Coast Guard (CCG) in developing alternative options for the CCG fleet renewal program (FRP).

QinetiQ has a consulting business called QinetiQ Advisory Services (QAS) which promotes the application of operational analysis (OA), cost engineering and other disciplines related to complex decision making. QinetiQ was formed in July 2001, when the UK Ministry of Defence (MOD) split its Defence Evaluation and Research Agency (DERA) in two. The smaller portion of DERA was rebranded Dstl (Defence Science & Technology Laboratory) and this remains part of the MOD. The larger part of DERA, including most of the non-nuclear testing and evaluation
establishments, was renamed QinetiQ and prepared for privatisation. QinetiQ became a public private partnership in 2002 [1].

This paper will focus on the methodology used to develop this body of work for the CCG, the tools, information sources employed and conclude with a discussion of the results.

Study approach

In response to a CCG request of proposal, QAS produced a tender and competitively won a study to consider the FRP. The proposed approach was an incremental study, see Figure 1, Phase 1 of which started in February 2017 until March 2017.

**Figure 1: Study approach – the proposed solution**

The main body of the study, Phase 2, was conducted from April 2017 to August 2017. The outcome of this phase of work resulted in a follow on phase (not shown in Figure 1) to consider refinements to the baseline options, for example the influence of vessel life extensions.

The Concept of Analysis (COA) was generated and reviewed with stakeholders to agree the approach prior to further work commencing. It is important to appreciate that QinetiQ did not start with the pre-conception that an equipment Capability Gap existed.

The concept of analysis flow diagram in Figure 2 provides an overview of the modelling approach. The requirements that the CCG are legally and nationally required to complete were established to provide a boundary of the analysis. Capability of the individual vessels were determined including the existing vessels and new vessels currently under construction to represent the capability of the future fleet. Through a comparison of the vessel capabilities and CCG requirements it was possible to determine the fleet effectiveness and associated total cost of ownership (TCO).

The basic “Do Nothing” option looked at the legacy fleet, known as Fleet Mix Option 1 (or FMO 1), to conduct only essential maintenance and repair until each vessel’s end of service life, and
procure those contracted already, but nothing else. The next option (FMO 2) was to consider the existing Fleet Renewal Program (FRP2012), before considering more alternative radical options including the introduction of Multi-Purpose Vessels (MPVs), Offshore Patrol Vessels (OPV’s) and Icebreakers.

The costs were generated in terms of the Total Cost of Ownership (TCO) this was the estimated cost across the life of the vessel from acquisition, through operation, to disposal. At the COA stage it was recognised that the TCO generated would be used for:

- **Financial Analysis** - inspecting costs by Financial Year, including inflation effects to enable CCG to anticipate where costs may exceed the funding available and require adjustments in order for the overall programme to remain affordable;
- **Economic Analysis** - this approach provides a normalised view of TCO for all options with future year dollars de-escalated and expressed as Net Present Value (NPV). The objective was to determine the Value for Money (VfM) for similar options and therefore the VfM for the Canadian taxpayer.

Figure 3 provides an overview of the process used to establish the TCO for the fleet. In general terms this consists of initiating the estimating process, documenting the data sources and assumptions, modelling the cost data and generating output reports in a consistent format.
Figure 3: Total cost of Ownership – the process to establish the TCO

**Requirement**

The operational analysis (OA) model represents the service delivery requirements placed upon the CCG fleet. The model was developed using the simplest formulation possible avoiding unnecessary complexity, whilst reflecting the CCG mandate. The key is to this modelling was to interpret the icebreaking need defined in the national marine advisory board [2.] and other historic activities. This resulted in:

- what was required,
- where it was required, and
- when it was required.

To check the validity of the model input data it was exposed to the CCG and agreed by CCG to be representative of the demands on the fleet together with the prioritisation. International obligations on the Canadian Government are at the top of the list, although icebreaking is important, search and rescue (SAR) and environmental response (ER) are higher priority, and in reality icebreaking vessels will be called off task to conduct SAR and ER.

**Assumptions and Limitations**

The OA modelling assumptions evolved over the course of the study with progressive development of these assumptions as QAS learnt more about the requirements. These included the representation of the vessels’ capability, availability the balancing of activities across the requirements and so forth. The modelling started with the assumption that new vessel construction would commence following planned vessel construction.
The OA master data and assumptions list (MDAL) recorded the data sources and the assumptions of the operational effectiveness. As seen in the extract in Table 1 different vessels have different capabilities and ability to achieve the CCG requirements.

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<th>Medium Icebreaking</th>
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<th>Light Icebreaking, Offshore</th>
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Table 1: OE MDAL – extract from the operational effectiveness master data and assumptions list.

In a similar manner the cost data sources and assumptions were captured in a cost data and assumptions list (CDAL). The CCG challenged QAS to generate the TCO without reference to their historical data. The maintenance costs in particular were considered to be constrained by budgetary pressure and therefore not representative of planned future expenditure. To provide confidence in the cost estimates generated QAS applied multiple cost estimating methodologies including:

- analogous
- parametric
- analytical

All OA and cost documented assumptions were reviewed and agreed with CCG subject matter experts (SMEs). Furthermore the assumptions have been tested with sensitivity analysis.
Modelling Methodology

QinetiQ has significant relevant experience in the creation of models of both operational effectiveness (OE) and cost. The model for the CCG was developed using the simplest formulation possible avoiding unnecessary complexity; re-using models and components when relevant to provide value for money to the CCG.

The OA modelling produced many outputs. The model determined the new vessel construction time, then for each region and season the vessels availability. Using a Linear Program optimiser the model established the optimised capability placing the priority weighted value; SAR being the most valued. The outputs from the OA included the proportion of each capability met for each season, use of each vessel, silt charts, composite fleet mix, and so forth.

The measure of effectiveness (MOE) had a value between 0% and 100% where the higher was the better outcome. It was a measure of the proportion of requirement met, recognising that there is no credit for over-delivery as excessive hydrography, for example, cannot substitute for insufficient icebreaking.

The cost modelling was influenced by the fleet mix and schedule for the phasing of the costs. Multiple cost methodologies were captured in the CDAL together with the potential deviations from the baseline plan in terms of risks and opportunities. These were fed into a cost model to be aggregated using Monte Carlo analysis as shown in Figure 4.

Figure 4: Modelling methodology – Total Cost of Ownership

The modelling and data was exposed to CCG SMEs who were able to understand and perceptively comment on them.
Verification & Validation

The analysis was independently reviewed within QAS before CCG delivery. QAS establish and maintain business, quality, safety and environmental management systems to enable certification to ISO and other relevant standards.

Also, this was not a desk analysis, QAS engaged with stakeholders to verify and validate data, method and results. Stakeholder engagements continued throughout the project with 5 Federal Departments, 200+ CCG employees, 19 Client One-to-Ones, 7 Ship Visits, 12 Site Visits, 15 Workshops and 22 Commanding Officers.

Sensitivity analysis was conducted to confirm the model reacted as expected and identify whether individual assumptions drove the conclusions. Hand calculations and scrutiny of outputs, for example Figure 5, were used to explain dips and rises in capability. Comparing patterns between runs and comparisons with historical data sets showed when shortfalls in capability predicted by the model aligned with those that were actually experienced.

![Figure 5: Validation – sanity check.](image)

The Capability Gap

QAS did not start with the pre-conception that an equipment capability gap existed. However, the capability in 2018 is lower than in the recent historic attainment. Without action the capability will degrade to only a residual capability by 2039. Figure 6 shows that action to resolve this gap cannot be deferred. Some vessels are already beyond their intended life. The capability gap can only be addressed by additional vessels (new construction, lease or purchase). Vessel life extension (VLS) will delay the gap, but will not prevent it.
Options and Results

During the study a number of options evolved; fleet mix options (FMO). For each option the effectiveness of the FMO was plotted over time and the TCO established for the vessels available.

As a baseline, FMO 1 was generated, see Figure 7. It is possible to see that the capability rapidly declines as the capability gap appears. As such, this option does not deliver the necessary capability and should be discounted as an option.
As an example of another option, in Figure 8 it is possible to consider the provision of a fleet with comparable vessel types to the current fleet. This shows FMO 2A results in further capability decline until 2041 (65%), and then never recovering above 80% capability. FMO 2B and FMO 2C also have capability decline and an 80% new-fleet plateau. The peak size of this fleet is insufficient to meet the requirement.

![Figure 8: Options and Results – FMO 2](image)

In addition, the options had the financial analysis calculation (Figure 9), but these should not be viewed in isolation without the relevant effectiveness result.
The financial analysis includes consideration of the uncertainty in the estimating accuracy and potential deviations from the baseline plan resulting from risks and opportunities. As seen in Figure 10 each option had a possible range of cost outcomes plotted against confidence. When s-curves overlap, it is not possible to distinguish between the options on a cost basis alone.
As with the Financial Analysis, the net present value (NPV) results still overlap, see Figure 11, making it impossible to identify the preferred option. As these options still have varying levels of effectiveness, the costs must be considered in combination with the OE results.

Figure 11: Options and Results – Economic Analysis

The graph in Figure 12 finally provides a combined view of the options showing the operational effectiveness and the investment appraisal. The chart needs to be interpreted with care; the horizontal axis has error bars showing the likely range of cost derived from the uncertainty and risk analysis. The vertical axis has a range bar showing the variation on achievement of the requirements over the date range assessed. It can be seem that no option achieves 100% of the requirement consistently and it can be observed that lower cost options may simply deliver less.
From this chart it is possible to deduce, as stated earlier, that the FMO 1 option (grey ellipse) is not sustainable. Furthermore, that the FMO in the red ellipse are far less effective than the FMO options in the blue ellipse while having a similar total cost of ownership.

The overlapping MOE results make it difficult to make a technical recommendation between the FMO options contained within the blue ellipse. The overlapping cost results make it difficult to make a financial recommendation without appreciation of the full context.
References

[1.] www.QinetiQ.com


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