Modeling Future Force Demand: Force Mix Structure Design

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Abstract

The Canadian Defence strategy *Strong Secure Engaged* published in 2017 mandates that the Canadian Armed Forces the CAF should be able to simultaneously defend Canada, including responding concurrently to multiple domestic emergencies in support of civilian authorities, meet its NORAD and NATO commitments, and contribute to international peace and stability through three major (500-1500 personnel) and four minor (100-500 personnel) operations. An initial, rudimentary analysis of current force structure indicated likely gaps in a number of areas and contributed to the impetus for a more rigorous analysis under the Chief of Force Development organization. A methodology to model future force demand was developed and implemented. The methodology estimates near-term future demand through a set of scenario variants each with a corresponding notional force package. A Monte Carlo simulation using a custom-built Force Structure Readiness Assessment Tool considers 10,000 alternative five year futures consisting of various scenario and force package combinations, and enables statistical estimates of the types and numbers of required Force Elements. The outcome of this future demand analysis can then be compared against current Force Element inventories to identify gaps, shortfalls or affluences, and enable follow-on analysis of various courses of action to address deficiencies or to understand, manage and mitigate risk.

Key words: Supply-demand analysis, force structure, future operations

Introduction

The Canadian Defence strategy *Strong, Secure, Engaged* (SSE) published in 2017 [1] not only stated what type of engagements the Canadian Armed Forces (CAF) should expect, and what the Government of Canada's defence priorities were, but for the first time it explicitly mandated the concurrency requirements. More specifically, the CAF should be able to simultaneously defend Canada, including responding concurrently to multiple domestic emergencies in support of civilian authorities, meet its NORAD and NATO commitments, and contribute to international peace and stability through two sustained deployments of 500-1500 personnel, one time-limited (6-9 months) deployment of 500-1500, two sustained deployments of 100-500 personnel, two time-limited deployments of 100-500 personnel, one Disaster Assistance Response Team (DART) deployment, and one Non-Combatant Evacuation Operation [1]. A rudimentary analysis of current force structure was conducted indicating potential gaps or shortfalls in a number of areas which contributed to the impetus for a more rigorous and comprehensive analysis under the Chief of Force Development organization.

The analysis, a part of the Force Mix Structure Design (FMSD) component of the Defence Plan 2018-2023 [2], is to be executed in several stages. During the first stage, the analysis of the structure for Force Employment is being executed; follow on stages will analyze the Force Generation and Institutional Elements of the Canadian Armed Forces. In order to model the Force Employment demand, the Chief of Force Development organization supported by Defence Research and Development Canada Centre for Operational Research and Analysis (CORA), developed and implemented the Monte-Carlo-based methodology described in this paper. This methodology employed significant custom data collection, including coordinated development of the future employment scenarios. The military response to these scenarios was contextualized for different broad military effect focus areas (maritime, land, air, joint) and in differing operational support contexts (level of austerity, host nation support, logistics considerations etc.). The outcome of this future demand analysis can then be compared against current Force Element inventories to identify gaps, shortfalls or affluences, and enable follow-on analysis of various courses of action to address deficiencies or to understand, manage and mitigate risk.

The paper is organized as follows. First, the overall analysis process for Stage 1 is described. It is followed by the description of the FSRA model and modeling approach. Then, the analysis methodology is outlined, and finally, the findings, observations, and follow-on research are discussed.

Force Mix Structure Design as a Supply Demand Problem

In its very nature, the question whether a force structure suffices for potential future operational demand is a supply-demand analysis. This problem is similar to previous work related to workforce planning where the objective is to close any gaps between the resources an organization needs to carry out its mission (demand) and the resources it has (supply) [3].The supply is represented by the existing available force mix inventory, and the demand is represented by the expected CAF response requirements. In the case of joint force planning, this problem is highly complex, as it requires a variety of Force Elements on the supply side to account for differing effects delivery options in varied operational and operational support contexts, and it features diverse potential demand options with uncertain occurrence rates and durations. This problem was addressed on numerous occasions in the past by Canadian and allied militaries ([4] and references therein). A number of force structure evaluation models were developed in the past by CORA [5]; these models match supply to pre-defined demand, but do not estimate the demand itself. The challenge of these models lies in the fact that if the demand far surpasses supply, they would simply fail to identify a solution, but would not specify where the gaps were. Therefore, it was deemed prudent to separate the demand modeling from the overall supply-demand analysis in order to estimate demand and verify that the supply is sufficient to arrive at a feasible solution. Additionally, the demand modelling should enable future “what-if” iterations for new scenarios, re-evaluated rates of occurrence or duration, or assess the impact of specific supply gaps or shortfalls. As a result, a customized tool had to be developed for the FMSD analysis. This tool needed to be simple enough to enable consideration of a large number of possible futures, and yet flexible enough to accommodate the variability of the Force Elements. The resulting model is a simple scheduling program similar to the Tyche simulation developed for the Royal Canadian Navy’s fleet mix structure analysis [6], but with much simplified input. The details of the supply modeling are yet to be determined at the time of writing.

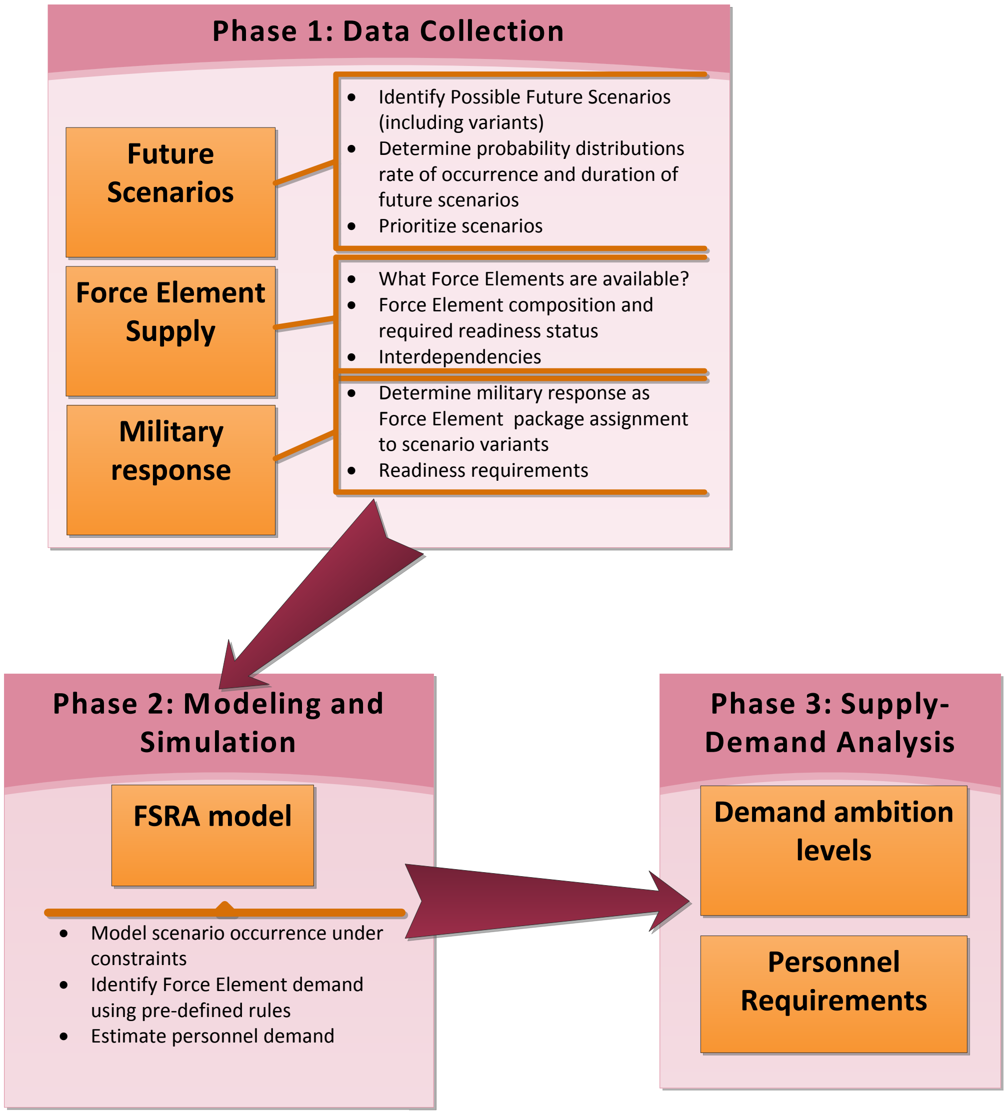

Figure 1: *FMSD Stage 1 process*

Force Mix Structure Design: Stage 1

Stage 1 of FMSD was executed in three phases (Figure 1), described below.

Data Collection

Due to the uncertainties with regards to possible future operations, modeling was performed in the form of a CAF response to particular scenarios representing a wide variety of security problems. The first phase was data collection of details for these particular scenarios. These scenarios do not attempt to predict the future, rather, they provide a somewhat rigorous cross-section of possible missions in the form of specific-enough geographical and operational context environments. As such, they provide background material for planning and assessment of resources for some notional future operations. A set of 17 scenarios covering a full range of missions mandated by SSE, with approximately 80 variants was developed specifically for FMSD. Various scenario variants correspond to different broad operational effect delivery options (e.g., maritime vs. land-centric operations, different available host nation support), and differing operational support contexts. The scenario details, prioritization, and associated notional Force Packages were collected/assessed in close collaboration with individual services (force generators and force employers). Scenario rates of occurrence and possible duration ranges were determined using a combination of historical analysis [6] and professional military judgement that included considerations addressed in analyses described in the Future Security Environment (FSE) [7]. In sum, the set of scenarios, the variants, and the rates of occurrence and durations represent the demand side of the model.

On the supply side of the model, data was collected on the existing available Force Elements including their size and detailed composition (occupation, low/high rank, and component). This was necessary because Force Employment structures often do not match garrison structures, and garrison structures are responsible, to various extent, for functions beyond Force Employment. This includes Force Generation, Force Management, Force Support, and Force Development. Additionally, some deployed structures are task-tailored amalgams drawn upon personnel from across the CAF, and have no corresponding garrison structure. Force Generation and Force Employment stakeholders were also requested to identify Force Element variants whenever the size or a composition of the elements differed for varying operational effects or support demands. This allowed for more specific matching of the best Force Element variant to a given scenario leading to notional force package mappings by scenario variant. This level of detail will in turn enable the post-modeling analysis to better identify potential gaps, shortfalls or affluences in the force structure.

Modeling future operational demand

In order to model the demand (Phase 2), a Force Structure Readiness Assessment (FSRA) tool was developed to support the FMSD process. FSRA is a Monte Carlo-based tool that can model concurrent operations based on imposed constraints, and the frequency/duration probabilities. It considers 12 lines of operations containing both constant demand (daily operations, North American Air Defence, high readiness forces, air mobility, Disaster Assistance and Relief Team, etc.) , and the additional seven lines of concurrent operations mandated by SSE (Figure 2).

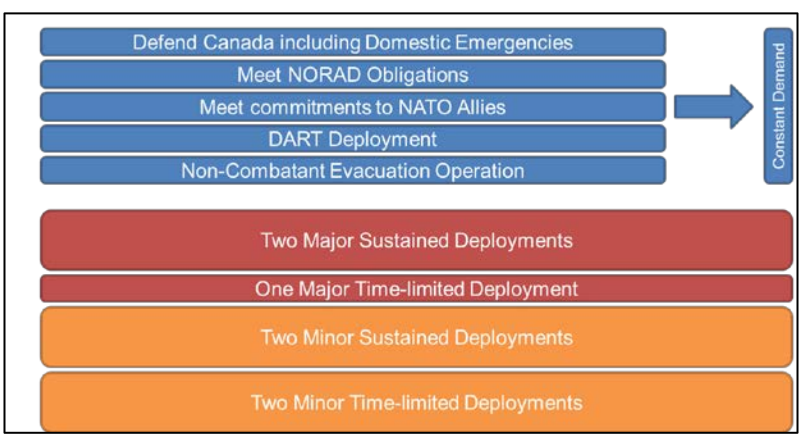

Figure 2: *Lines of operations modeled in FSRA*

Specifically, FSRA randomly computes a scenario combination (using frequency and duration inputs) over a predefined time period (for example, five years). An example of a three-year schedule is shown in Figure 3. It was obtained as follows. For each available slot a scenario was randomly selected using pre-defined rates of occurrence and assuming that they were from a Poison distribution. The selection was further limited by pre-defined constraints (e.g., number of scenarios of a similar type, or which scenarios were allowed for each line of operations). If a scenario was selected, its notional duration was selected using pre-defined probability distributions corresponding to each scenario. The selected scenario was then assigned to the corresponding slot for an appropriate number of subsequent time steps. Once the scenario ended, the slot became empty again, and a new selection was conducted. The selection was repeated for each time step for the desired time duration (e.g., five years). If no scenario were selected, the slot remained empty until the next time step. In order to avoid the boundary effects during the simulation start up, the simulated period was longer than the actual analyzed period, and the initial several years are cut off. For example, in order to use a five year period for the analysis, the simulation is run for notional ten years. Two-month increments were used; the initial sensitivity analysis for five-year scenario duration suggested that using shorter sampling was not necessary.

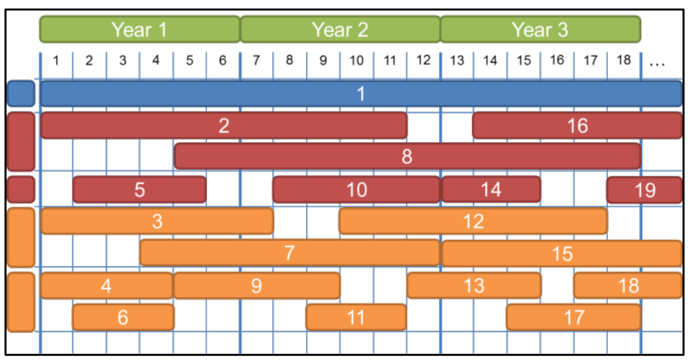

Figure 3: *Sample scenario variant assignment in FSRA.*

Once the scenario combination is determined for a particular time sample, an aggregated list of required Force Elements and their quantities is obtained using pre-defined mapping of the elements to each scenario variant (from Phase 1). This step is deterministic, based on the predetermined force packages mapped to each scenario using professional military judgement. The Force Elements required under the constant demand are then added to the mix. The composition of selected packages corresponded to current CAF force structure; there were variants and modifications to the Force Elements depending on the operational context and logistics and sustainment requirements. For instance, a squadron of F18s would require different support team structure at their home base (where a lot of the maintenance and sustainment task are addressed via force-generation and Force Development structures) and at some austere airstrip in a third country location. The size of Force Elements varied from few personnel for some headquarters roles to an infantry company or a frigate. The mission initiation and mission closure activities were not considered; i.e., the demand was considered uniform for the entire mission duration. Furthermore, since Stage 1 of FMSD did not consider itself with the Force Generation, the Force Elements were assumed required only for the mission duration (i.e., as soon as the mission was over, the Force Element would be back in the pool. This could be interpreted as a Force Element replacement from the Force Generation pool. For the analysis purposes, 10,000 possible futures are analyzed; that means that for a trial representing a five-year interval with two-month sampling a typical run yields 300,000 discrete time period samples that can be analyzed either together, or by individual five-year trial.

Analysis

The preliminary analysis (Phase 3) looked at the personnel demand stemming from the employed Force Elements. Instead of treating each trial period separately, the first round of analysis looked at the cumulative results across all sample points (300,000 points). The following questions were addressed during the preliminary analysis:

- Which Force Elements were used at each sampling point?
- What was the total personnel number for all Force Elements necessary to meet the concurrency demand for a given percentage of demand (i.e., 240K time periods equates to 80% of overall demand)?
- What was the maximum number of personnel required to provide all the Force Elements required for a given percentage of demand (i.e. 240K time periods equates to 80% of overall demand)?
- What was the average ratio of personnel in support of constant demand, sustained operations or surge operations?
- Which Force Elements were used most/not used at all?

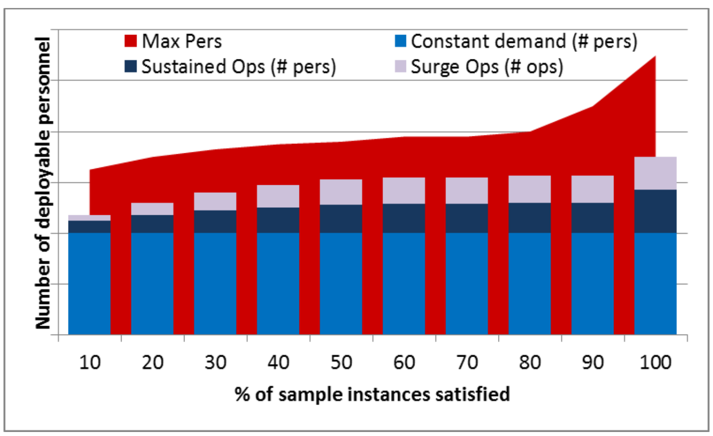

Figure 4: *Example of FSRA results (not actual numbers).*

Figure 4 shows an example of what the results would look like. This example does not use the actual numbers; it is intended only as an example of the general form of the actual results. The light blue colour represents mean number of personnel (irrespective of specific Force Elements) for constant demand, and the dark blue and purple correspond to the sustained and surged personnel required for the additional seven lines of operations. In contrast, the red area denotes the maximum number of personnel required for all the Force Elements. For instance, in one trial the employed element might have been an infantry company, in another an offshore patrol vessel. Both of these would average to similar numbers of personnel (blue or purple); however, since they are not interchangeable, the combined number of people would be needed to meet the requirement to have either of the two Force Elements available.

More detailed analysis is planned, including the sensitivity analysis, analysis of confidence, and frequency/duration analysis of employment of particular Force Elements.

Summary

In order to assess the ability of the current CAF force structure to meet the concurrency demands of SSE, the FMSD analysis is currently being undertaken by the CFD organization. To estimate near-future demand, an in-house tool called FSRA was developed. This tool uses a set of notional scenarios with estimated likelihood of occurrence and duration, and the expected military response to estimate the number of employed personnel required to meet the scenario demand. The simulation uses 300,000 sample instances, obtained as 10,000 trials of a five-year period with two-month sampling frequency. A preliminary analysis of the results was done, and further analysis is being planned.

The present analysis did not consider the supply side of the relationship. The information for the supply analysis is now being collected in collaboration with the subject matter experts. Depending on whether the supply is likely to yield feasible solutions, additional analysis leveraging some of the existing models might be possible.

The main effort of the demand analysis will focus on the understanding of relationship between Force Employment demand and supply. This relationship will inform options for structural adjustments, and assessment of risks. The supply versus demand analysis will, in part, inform Force Generation and institutional requirements to sustain the Force Employment demand. The Force Generation and the Institutional elements will form the bulk of Stage 2 and Stage 3 of the FMSD analysis. Due to the complexities introduced by Force Generation and institutional sustainment (interdependencies, training requirements, demand for qualified trainers, attrition, procurement, etc.), including the presence of feedback loops between various requirements, the current methodology will not be expandable in a straightforward manner. According to the multiscale variation on Ashby's law of requisite variety [9], in order to control a multiscale complex system, the complexity of the controlled systems must be greater than the complexity of the original system at all scales [10]. As a consequence, multi-scale, renormalization-like approaches will need to be explored to deal with these additional complexities.

References

[1] Strong, Secure, Engaged: Canada's Defence Policy, Department of National Defence, D2-386/2017E, June 2017

[2] Execution – defence plan 2018-2023, https://www.canada.ca/en/department-national-defence/corporate/reports-publications/defence-plan-2018-2023/execution.html (Accessed 20 June 2019).

[3] Vernez, G., A. A. Robbert, H. G. Massey, and K. Driscoll, Workforce planning and development processes, a practical guide, RAND Corporation, Santa Monica, CA, USA, Tech. Rep. ISBN 978-0-8330-8597-9, 2007.

[4] Couillard, M., L. Arseneau, C. Eisler, B. Taylor, Force Mix Analysis in the Context of the Canadian Armed Forces, Proceedings from the 32th International Symposium on Military Operational Research, www.ismor.com (Accessed 20 June 2019), 2015.

[5] Wesolkowski, S., C. Eisler, Capability-Based Models for Force Structure Computation and Evaluation, RDC-RDDC-2015-N008, 2015.

[6] Bourque, A., C. Eisler, Fleet Mix Study Iteration II: Making the Case for the Capacity of the “Navy after Next”, DRDC CORA TR 2010–159, Aug 2010.

[7] The Future Security Environment 2013-2040, Chief of Force Development, http://publications.gc.ca/collections/collection_2015/mdn-dnd/D4-8-2-2014-eng.pdf (Accessed 26 Jun 2019), 2014.

[8] Dobias, P. Estimation of frequency and duration of future Canadian Armed Forces Operations, Proceedings from the 36th International Symposium on Military Operational Research, www.ismor.com (Accessed 20 June 2019), 2019

[9] Ashby W.R., Requisite variety and its implications for the control of complex systems, Cybernetica 1:2, p. 83-99. (http://pcp.vub.ac.be/Books/AshbyReqVar.pdf, Accessed 20 June 2019), 1958.

[10] Bar Yam, Y., Multiscale variety in complex systems, Complexity, 9, 4, 37–45, 2004.