The Department of National Defence Strategic Cost Model

Volume II- Theory and Empirics

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Defence R&D Canada
Centre for Operational Research & Analysis

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Canada

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Abstract

The production of defence capabilities is based on the principles of constrained maximization. That is, it is a process that maximizes the military capability achievable from a given budget with a given defence technology and a given set of input prices. The first step in this process is to develop a model or a process that can estimate the total cost of producing military capabilities. This paper discusses such a model, developed in Defence R&D Canada, with particular emphasis on the economics and operational research methodologies underpinning the modeling framework. From an economics perspective the model is a hybrid of a multi-product or joint output production function and a simplified Input-Output model. A number of simulations are conducted and the paper highlights some of the strategic level results and their associated implications on the Canadian Forces and the Defence Capability Planning process.

Résumé

La production des capacités de défense repose sur les principes de l'optimisation restreinte, c'est-à-dire un processus qui maximise la capacité militaire réalisable à partir d'un budget donné, d'une technologie de défense donnée et d'une série donnée de prix à l'entrée. La première étape du processus consiste à élaborer un modèle ou un procédé permettant d'estimer le coût total de la création de capacités militaires. Cette communication présente un modèle de ce type, élaboré par R & D pour la défense Canada, en accentuant les facteurs économiques et les méthodes de recherche opérationnelle qui sous-tendent la structure de modélisation. D'un point de vue économique, le modèle est un hybride de multiproduits, ou d'une fonction de génération de données de sortie, et d'un modèle entrées-sorties simplifié. Un certain nombre de simulations sont réalisées, et l'on présente certains des résultats de niveau stratégique et leurs implications pour les Forces canadiennes et le processus de planification des capacités de défense.

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Executive summary

The Department of National Defence Strategic Cost Model: Volume II- Theory and Empirics

Binyam Solomon, Paul Chouinard, Leonard Kerzner; DRDC CORA TR 2008-03; Defence R&D Canada – CORA; October 2008.

The first volume in this series by Chouinard and Wood [4] presents and discusses the various issues that need to be considered in constructing a "strategic cost" model as well as describing the Cost Model's overall structure and the rationale for the choices made in its development. This second of three volumes describes the theory and selected outputs of the model. Specifically, this volume presents the theoretical underpinnings from economic and operational research perspectives and highlights some of the macro-level results of the Department of National Defence's (DND) first integrated Strategic Cost Model (SCM).

The allocation of scarce resources among alternative and competing demands is the central tenant of economics and it is also the case for both the Federal government and the Department of National Defence. An examination of the country's macroeconomic condition reveals that fiscal prospects have improved substantially since the mid-1990s. The tight fiscal restraints that brought the balanced budget, however, have hindered the efficient delivery of many public services including health and defence. In addition, the declining standard of living and the gap in productivity between Canada and its largest trade partner, the United States, are now the main policy topics crowding the ever-increasing demand for stable funding.

The management of defence resources is also constrained by policy directives such as the expenditure management system and other government mandates and initiatives. Thus there may be unavoidable corporate overhead costs that may not directly or indirectly contribute to defence capabilities but nevertheless are required from a government-wide perspective. These policies may also result in mutually exclusive goals of cost-effective delivery of government services (such as defence) and regional development plans. For example, a decision to "mothball" ships may be contrary to an overall government of Canada industrial-regional initiative that requires a dockyard in a region to remain operational.

The optimal allocation of defence resources in a constrained budget and policy environment is a complex task. This activity is made all the more complicated due to the dynamics and interdependencies among expenditure types and production technologies. One of the main strengths of the SCM is its ability to bring simplicity, clarity and order to the relationships that govern the constrained optimization problem. Once the Capability Based Planning process is institutionalized the benefit side of the equation will be clearer and the optimization problem more transparent.

In order to insure wider distribution, the empirical section of this volume utilized generic examples and in some cases hypothetical outputs. However, the SCM does provide insights from the tactical viewpoint, such as the personnel requirements (both military and civilian) for a marginal increase in a given capability, to the strategic viewpoint (Canadian Forces perspective) such as the impact of transferring some capabilities to the reserve units or other government

departments. As an example of the former, simulation results on personnel requirements using the SCM showed that the naval capabilities of destroyers and frigates respectively require three and two personnel indirectly or in support for every one that is directly employed while air assets of maritime helicopters and tactical fighters have a higher indirect support at four and five personnel respectively for every direct employment. The indirect personnel requirement stems from infrastructure and equipment support for the platforms associated with these capabilities. The detailed attribution of costs inherent in the SCM is similar to the Input-Output models used extensively by economists and operational researchers.

The SCM can also provide insights about centrally managed projects/programs – such as training. According to one simulation result, the average cost of all training is estimated at $1.7 billion, with Common Training at about $700 million, Land Training at $500 million and Air and Sea Training at about $250 million each. These costs are in constant year dollars and exclude the effect of inflation.

As pointed out in the first volume in the series, all models "do violence to reality" and the SCM is no exception. In addition to model enhancements discussed in Volume I, this volume also makes suggestions for future research, specifically:

1. Exploiting the rich data set to understand the interrelationship among the environments and their respective inputs and outputs;

2. Recognizing the heterogeneity of capital assets and making allowances for the difference in the rates of depreciation;

3. Assessing the possible tradeoffs between reserves and regular forces personnel by disaggregating available military pay data and treating human capital as fixed in the short-run and variable in the long run; and,

4. Estimating total factor (capital and labour) or labour productivity measures for the military.

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Dans le premier volume de cette série, les auteurs Chouinard et Wood [4] présentent et examinent les divers éléments à prendre en considération au moment de l'élaboration d'un modèle des « coûts stratégiques ». Ils décrivent également la structure globale du modèle des coûts et justifient les choix effectués durant son élaboration. Dans ce deuxième volume de la série de trois, on explique les principes et certains résultats du modèle. Ce volume expose plus précisément les fondements théoriques dans une perspective économique et dans l'optique de la recherche opérationnelle et il fait ressortir certains des résultats à l'échelon macro-économique du premier modèle des coûts stratégiques (MCS) intégré du ministère de la Défense nationale (MDN).

La répartition de ressources peu abondantes en fonction de demandes diverses et concurrentielles est le principe de base de l'économie, de même qu'une réalité du gouvernement du Canada et du ministère de la Défense nationale. Un examen de la situation macroéconomique du pays révèle que les perspectives financières se sont améliorées sensiblement depuis le milieu des années 1990. Les restrictions financières rigoureuses à l'origine de l'équilibre budgétaire ont cependant nui à la prestation efficace de nombreux services publics, dont ceux de la santé et de la défense. De plus, la qualité de vie décroissante et l'écart de productivité entre le Canada et son plus important partenaire commercial, les États-Unis, sont devenus des enjeux de politiques qui influencent la demande sans cesse croissante de financement stable.

La gestion des ressources de défense est aussi limitée par des orientations de politiques comme le système de gestion des dépenses et par d'autres mandats et initiatives gouvernementaux. Il peut donc y avoir des frais généraux inévitables sans lien direct ni indirect avec les capacités de défense mais qui seraient tout de même nécessaires dans une perspective gouvernementale. Ces politiques peuvent également engendrer des objectifs mutuellement exclusifs tels la prestation de services gouvernementaux (comme la défense) rentables et la mise en œuvre de plans de développement régional. Par exemple, une décision de mettre des navires « en gardiennage » pourrait aller à l'encontre d'une initiative industrielle et régionale du gouvernement du Canada qui exigerait que l'arsenal maritime d'une région reste en service.

La répartition optimale des ressources de défense dans les limites d'un budget réduit et dans un contexte de politiques publiques est une tâche complexe. Elle se complique davantage devant la dynamique et l'interdépendance des types de dépenses et des technologies de production. Une des grandes forces du MCS est sa capacité de simplifier, de clarifier et d'harmoniser les rapports qui sous-tendent l'optimisation restreinte. Une fois que la planification axée sur les capacités sera adoptée à l'échelle organisationnelle, l'aspect avantageux de l'équation se précisera et la difficulté de l'optimisation deviendra plus évidente.

Pour en élargir la distribution, la section empirique de ce volume utilise des exemples génériques, et dans certains cas, des résultats hypothétiques. Cependant, le MCS ne donne aucune indication du point de vue tactique, comme les besoins en personnel (tant militaire et que civil) liés à l'accroissement marginal d'une capacité donnée, ni du point de vue stratégique (perspective des Forces canadiennes), comme l'impact du transfert de certaines capacités aux unités de la Réserve ou à d'autres ministères. À titre d'exemple de ce qui précède, les résultats d'exercices de simulation concernant les besoins en personnel effectués à partir du MCS indiquent que les capacités maritimes des destroyers et des frégates nécessitent respectivement trois et deux personnes à titre indirect ou en guise d'appui par personne employée directement dans ce secteur, tandis que les ressources aériennes des hélicoptères maritimes et des chasseurs tactiques génèrent un plus grand soutien indirect, soit quatre et cinq personnes respectivement par emploi direct. Le besoin de personnel indirect découle du soutien en infrastructure et en équipement que requièrent les plateformes connexes. L'attribution détaillée des coûts inhérente au MCS s'apparente aux modèles entrées-sorties dont les économistes et les préposés à la recherche opérationnelle font grand usage.

Le MCS peut aussi donner des indications relativement aux projets/programmes gérés par l'administration centrale – comme l'instruction. Selon les résultats d'une simulation, on estime le coût moyen de l'instruction globale à 1,7 milliard de dollars : l'instruction commune à toutes les armées à quelque 700 millions de dollars, l'instruction de la force terrestre à 500 millions et l'instruction des forces aérienne et maritime à environ 250 millions de dollars chacune. Ces montants sont exprimés en dollars annuels indexés et ne tiennent pas compte de l'inflation.

Comme il est indiqué dans le premier volume de la série, tous les modèles « font violence à la réalité » et le MCS ne fait pas exception. Outre les améliorations au modèle présentées dans le premier volume, ce document propose également des pistes de recherches éventuelles :

1. exploiter le riche ensemble de données pour comprendre les rapports mutuels entre les milieux et leurs entrées et sorties respectives;

2. reconnaître l'hétérogénéité des biens immobilisés et tenir compte des différents taux d'amortissement;

3. évaluer les échanges de personnel possibles entre la Réserve et la Force régulière en désagrégeant les données disponibles sur la solde militaire et en traitant le capital humain comme fixe à court terme et variable à long terme;

4. faire une estimation du facteur total (capital et main-d'œuvre) ou des mesures de productivité de la main-d'œuvre à l'intention des forces armées.

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1 Introduction

1.1 Background

This document is the second part of a three part series of reports documenting the Department of National Defence's (DND) first ever Strategic Cost Model (SCM). The first volume described the background and the logic associated with developmental options for this integrated model [4]. This volume treats the model from a theoretical perspective with particular emphasis on the economics and operational research methodologies underpinning the modeling framework. It also highlights some of the strategic level results made possible by the model and their associated implications to the Canadian Forces and the Defence Capability Planning process. The third volume will be a users' guide whose aim is to provide a detailed account of the model contents, its structure and its processes to show those responsible for model maintenance how to update information, execute relevant queries, and produce desired tables and charts.

As pointed out in the first volume of this documentation effort, the rationale for developing the SCM is to inform and provide a fiscal framework for the implementation of capability based planning and the Defence Capability Plan (DCP) through an estimate of the future, budgetary cost of the Defence Policy Statement [4]. From an economic perspective, the model generates insight into what is effectively a constrained maximization problem. It is assumed that there is a utility function in the minds of decision-makers that can impose order upon the combinations of military personnel, infrastructure, capital and so on such that one combination is considered better than another combination of resources in meeting a national objective for Defence. These goods or services are constrained by resources (budget), technology (production) or institutional factors. Thus, insofar as economics can be applied to DND, its application is bounded by the existence of this utility function. While this economics formulation of the optimization problem is generally confined to classical methods based principally on calculus, operational research methods do provide a more generalizable framework. For example, the military decision maker discussed above may face a budget constraint of say $200M. In operational research techniques such as mathematical programming, this budget constraint may be specified as less than or equal to $200M. By liberalizing the constraint requirement (in economics the formulation is strictly equal to), this new framework of optimization makes the problem simultaneously interesting and realistic, as robust options emphasizing a broader range of desirable capabilities may be presented at little additional cost to which otherwise would have been an infeasible constraint.

The theoretical features of the SCM are discussed in this volume along with exogenously determined constraints such as domestic economic factors, defence policies and politics. Since the budget and policy constraints are treated as given, there are no formal treatments of these constraints in the SCM. However, the need for choices between competing military capabilities is made all the more difficult by these constraints. The determinants of defence expenditures and the overall government budgeting process are often considered technically complex and generally not well understood by the public. However, the lack of rigor in the analysis of Canadian defence posture constrains informed decisions on defence policy formulation and the allocation of scarce public funds among competing programs. In the absence of reasoned debate and scrutiny, myths and anecdotes persist. Thus, the government's budgeting process and other policy constraints are discussed in some detail to inform the remaining constrained maximization problem.

The purpose of this paper is to present the theoretical underpinnings from economic and operational research perspectives and to present some of the macro-level results of the SCM.

1.2 Scope, Assumptions and Principles

The theoretical discussion of the SCM rests on the concept of constrained maximization with an operational research extension through linear programming and an input-output methodology. These concepts, which are discussed in detailed in subsequent sections, form the basis of the theoretical discussions. Constrained optimization implies an objective function that is either a quantifiable output or utility. This study utilizes the latter based on criteria that are assumed to reflect key aspects of the Defence Policy Statement and overall DND and Canadian Forces (CF) strategy. The empirical portion of this study highlights the marginal costs of selected capabilities, the implications of force expansion, the cost of common and environment-specific (army, navy and air force) training, the cost benefit trade-offs of individual capabilities.

1.3 Document Structure

The next section presents the stylized facts about the Canadian fiscal and economic environment and the associated implications to DND's resource allocation challenge. Section 3 discusses Capability Based Planning (CBP) and how this management process can be used to derive a military utility function. Section 4 highlights the key attributes of the SCM including an input-output and multi-output production function representation. Some of the data problems and solutions are also discussed in this section. Section 5 presents some of the main findings of the SCM and the final section 6 summarises the theory and empirics of the SCM and points to future research agendas.

2 Canadian Fiscal and Economic Environment

The resource allocation challenge of the Department of National Defence (DND) is a subset of the Government of Canada's own challenge of funding its policies and programs within available fiscal room. These Federal government policies are often communicated, in broad terms, through the Speech from the Throne. Allocating specific funds through the Federal Budget operationalizes the specific priorities outlined in the Speech. While the Speech gives the general short-term direction of the Federal government, policy statements and White Papers provide more precise expectations and directions of the central government to specific departments or policy areas. The 2005 Defence Policy Statement (DPS) is one such direction and one that specifically pertains to defence.

Fortunately, Canada has been running a positive government balance (revenues less expenses) for over a decade as a result of prudent financial management and positive economic conditions fostered by favourable trade arrangements (The North American Free Trade agreement), and strong global demand for Canadian natural resources.[1] It is also conceivable that the growth in exports during the last decade 1997-2006 has much to do with the depreciating dollar improving the country's cost competitiveness and the strong US economy generating significant demand for Canadian goods and services.

Despite this growing economic linkages, Canada's productivity and real income performance lagged far behind the United States (US) in the 1990s and the Canada-US productivity and real income level gaps, widened significantly, contrary to expectations. Indeed, the Canadian Government and Canadians are acutely aware of the slippage of their relative standard of living against their American counterparts (measured as Gross Domestic Product-GDP per population). Table 2 shows productivity and income trends of the Canadian economy as a percentage of US variables. Gross Domestic Product (GDP) per capita increased steadily throughout most of the 1970s and peaked at 91% of the U.S. level in 1981. Since then, there has been a comparative decline in the Canadian standard of living compared to the US. In 2006, the Canadian rate stood at 83.8% of that of the US value indicating Canadians are about 16% poorer than their primary trade partner. A primary reason for the gap can be explained by general productivity measures.

For example, GDP per worker and GDP per hour worked have declined against the US since the mid-1970s. In 1978, GDP per worker peaked at 95% of the US rate and since started to decline until it reached its lowest level in 2006 at 83%. Similarly GDP per hours worked peaked at 91% of the U.S. in 1984 before declining to its 2006 level of 81%.

[1] Cox, D. J., and R. G. Harris, "North American free trade and its implications for Canada: Results from a CGE model of North American trade," The World Economy, Vol. 15, 1992, pp. 31-44.

Table 1: Relative Income and Productivity Levels (Canada as % of US)

	Per Capita				
	GDP per capita	PI per capita	PDI per capita	GDP per worker	GDP per hour
1961	83.93	66.32	67.23	92.90	83.98
1965	84.36	67.87	67.53	90.52	84.77
1970	86.52	72.22	67.70	92.92	87.79
1975	91.08	86.52	79.89	92.40	87.51
1980	90.86	91.03	86.47	93.90	90.56
1985	88.07	86.33	79.50	92.40	90.81
1990	84.64	88.02	78.13	89.10	86.83
1995	82.84	83.60	73.52	89.92	89.01
2000	82.84	77.14	68.79	88.42	87.21
2001	84.67	77.75	69.17	89.25	87.42
2002	86.16	78.25	68.53	87.67	86.59
2003	85.59	78.63	68.29	85.27	84.33
2004	84.17	78.94	68.34	83.37	81.60
2005	84.32	79.78	69.32	83.39	82.19
2006	83.83	80.44	70.74	82.60	81.41

Source: Centre for the Study of Living Standards (www.csls.ca)

The reasons for this discrepancy have been the subject of much debate in Canada with no definitive answer available to account for it completely. A telling factor may be Canada's taxation levels which may be responsible in discouraging talent to remain in or migrate to Canada, as personal income (PI) and after tax (disposable) income (PDI) have been consistently lower during this time horizon - currently 80 and 71% of the US rates respectively.

The concern about the declining standard of living and productivity lags has prompted the Federal Government to make it one of the central themes in Speeches from the Throne since 2000. In addition, the aging population is bringing public health back onto centre stage after a brief absence in the immediate aftermath of September 11 when security concerns were emphasised. In spite of this, the Defence portfolio did receive funding increases in the 2000, 2002 and 2005 budgets.

Despite healthy fiscal conditions and the general understanding of the "rust-out" of CF capital assets, defence faces challenges in acquiring a larger piece of the discretionary funding in contrast to publicly popular programs such as health care and infrastructure spending. Notwithstanding recent pronouncements regarding asymmetric threats (terrorism), increased North American security issues, and the Canada First Defence Strategy, the exigencies of a minority government limit its potential for adopting any long-term, considered plan to provide DND/CF with stable funding and to engage fully in transformative Capability Based Planning.

In addition to the macroeconomic aspects discussed above, the Canadian economy faces a number of near-term uncertainties. First, the boom in Western Canada is highly dependent on commodity prices remaining firm while the sluggish manufacturing sector in Eastern Canada must contend not only with a rising Canadian dollar but also with increasing competition from emerging countries such as China and India. Second, open economies such as Canada's thrive under international trade regimes that foster free trade. However, there are growing protectionist sentiments around the globe - particularly in the US. Lastly, the Canadian government has yet to deal with inter-provincial trade barriers and a non-uniform financial regulatory regime both of which discourage the free flow of capital from where it is available to where it is needed.

2.1 Fiscal Environment

According to the International Monetary Fund (IMF), Canada is expected to remain the only Group of Seven (G7) member with a positive government balance until 2009 (Table 2).

Table 2: General Government Balance as a Percentage of GDP

Country	2005	2006	2007	2008	2009
Canada	1.569	1.032	0.984	0.1	0.028
France	-2.951	-2.526	-2.389	-2.764	-3.022
Germany	-3.367	-1.607	0.01	-0.676	-0.427
Italy	-4.231	-3.354	-1.9	-2.477	-2.523
Japan	-5.042	-3.766	-3.385	-3.364	-3.257
United Kingdom	-3.401	-2.555	-3.015	-3.057	-3.199
United States	-3.591	-2.613	-2.492	-4.468	-4.175

Source: [12] Shaded figures indicate estimates

At the end of the 2006-07 Fiscal Year (FY), the Federal government spent $222B on a variety of ongoing programs and announced initiatives. It collected $236B in taxes resulting in a surplus of $14B. Until recently, its largest expenditure was the cost of financing the Federal public debt, which peaked at about 30% of total expenditures in 1996-97. This has declined steadily due to a continuing string of balanced or surplus budgets and with a commitment by the government to use a portion of its surpluses to pay down the debt (Table 3).

Defence accounted for 7% of total program spending and 25% of the government's operating budget (Total expenditures less debt financing and transfers) in FY 2005-06 and FY 2006-07. Since the 1990s, defence spending has maintained a consistent percentage of overall federal expenditures. It is important to recognize that 75% of Federal government expenses are statutory, limiting the government's flexibility in effecting significant policy re-direction in the short-term. These statutory expenses include transfers to other levels of government (health and social transfers including education funding), transfers to individuals (old age, employment insurance, etc.), and other transfers and subsidies (farm income assistance, First Nation communities, industrial and regional subsidies).

Given this short-term inflexibility in redirecting funding, the Federal government often has to apply sub-optimal budget allocation strategies such as department and agency-wide cost reductions (e.g. wage freezes) or operating budget reductions. Since defence accounts for a large portion of Federal government discretionary funding, it becomes a target for budget cutting. Even if the government decides to engage in appropriate strategies to optimize budgets among competing programs and departments, setting an appropriate valuation of public goods and services, such as defence is extremely difficult.

Table 3: Trends in Federal Government Expenditures

Year	Total transfer payments	Public Debt Charges	Crown Corporation Expenses	National Defence	Other departments and agencies	Total Expenses
1983-84	53.3%	20.9%	4.9%	7.4%	13.5%	100.0%
1988-89	49.3%	26.5%	3.6%	7.6%	13.1%	100.0%
1989-90	47.1%	28.4%	3.6%	7.6%	13.2%	100.0%
1994-95	50.8%	26.4%	3.1%	6.3%	13.4%	100.0%
1996-97	48.5%	29.8%	3.3%	5.6%	12.8%	100.0%
1998-99	49.9%	27.1%	3.6%	5.8%	13.5%	100.0%
1999-00	49.7%	26.8%	3.2%	6.2%	14.1%	100.0%
2004-05	56.4%	16.2%	4.2%	6.8%	16.4%	100.0%
2005-06	56.6%	16.2%	3.4%	7.2%	16.6%	100.0%
2006-07	56.2%	15.3%	3.2%	7.1%	18.2%	100.0%
		(Millions of Dollars)				
2006-07	$ 124,940	$ 33,945	$ 7,211	$ 15,732	$ 40,386	$ 222,214

Source: Fiscal Reference Tables (Department of Finance- 2007)

2.2 Public Perceptions

Unlike other areas for which it may be possible to derive clearly defined national benefit for a particular course of action, defence outcomes are most appropriately measured in terms of risks avoided – outcomes that are difficult to sell to an expenditure conscious electorate. In the absence of an unambiguous quantifiable measure of defence output, the government often finds its signal to support defence from public opinion polls. This is unfortunate since defence is a *pure* public good. This implies that the benefits from defence are necessarily **non-rival** and **non-excludable**:

1. Security provided by the CF, is *non-rival* among citizens because the ability of the armed forces to deter enemy aggression is independent of the size of the population.

2. The benefits of defence are *non-excludable* since they cannot be withheld at an affordable cost. We cannot stop {non-citizens or regions external to Canada} from benefiting from the protection afforded by the armed forces.

Since a citizen's *true* preference for defence is not revealed through the assignment of a "fair" cost of defence per citizen, *free riding* becomes a compelling option (free riders pay less than their fair share of the cost of a public good).[2] Notwithstanding the limitation of public opinion polls (results are not robust as they depend on how and when the questions are asked, for example); the Canadian public response to September 11 is very instructive on the public's view of defence. While immediate reaction of vulnerability, anger and shock was translated into an increase in the need for security, defence or security expenditures still ranked below health spending and economic growth. A subsequent poll a few months after the event showed that defence, terrorists' threats, etc. were no longer an issue of concern. Baker [1] also discusses previous polls that consistently rank defence below other public expenditure priorities despite the favourable image of the Canadian Forces in the public eye implying the resource trade-offs between defence and non-defence public goods is a factor that contributes to the determination of defence expenditures. The general lack of interest in matters of defence and security, however, is not uniform across the country. The Atlantic Provinces, which have a large army and navy presence, and the Prairies with an air force and army presence tend to support defence spending. In contrast, Quebec tends to be less favourable to defence spending increases or support despite the presence of land and air elements.

The Canadian public's lack of interest in defence matters is also reflected in the political system. Treddenick [27] points to political control only through budget constraints and bureaucratic procedures as well as the politics surrounding procurement. Most defence economics-related studies in Canada tend to focus on industrial policies and base closures [17]; [21]. The government response to the public's general lack of interest can be discerned by critically examining government expenditure trends.

Figure 1 shows the relative movement of defence and other federal departments' operating budgets in real terms (adjusting for inflation and defence-specific inflation - DSI). For illustrative purposes, the adjusted expenditures are indexed to equal 100 in 1993-94. During the period 1992-93 through to 1997-98, the government initiated a number of reviews to combat the Federal fiscal deficit. As Figure 1 shows, defence spending was cut deeper and more rapidly than other Federal departments during this period. In addition, recovery to initial funding levels was quicker for other departments, reaching this milestone by 1999-2000. In contrast, DND achieved this milestone in 2006-07. Note that this is despite the increases announced in Budget 2005 and 2006 and if factoring Defence-Specific Inflation (DSI), DND may only return to a 1990-level of real purchasing power in 2007-08. The notion of DSI is discussed briefly in the next section.

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[2] Note that the US defence of North America encourages wholesale free riding by Canadians- i.e. why do we need a Canadian Armed Forces when the Americans will do it anyway?

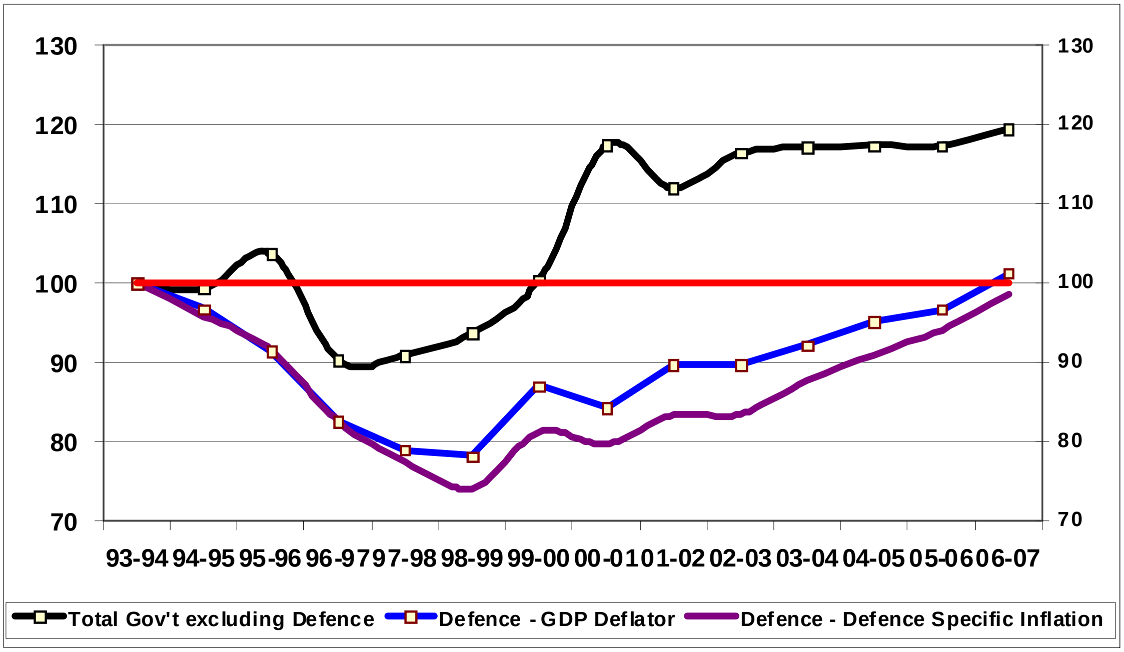

Figure 1: Federal Government Operating Budget Real Growth Index (1993-94=100)

3 Capabilities, Outputs and Utility Functions

While the SCM captures the full cost of capabilities and to some extent mimics an aggregate military production function, its main contribution is the conduct of a "cost effectiveness analysis" through the assessment of the costs of military effects which are themselves assessed in terms of their adequacy to deliver military capability as defined by the policy goals of the DPS [4]. The assessment of whether military assets deliver capabilities consistent with the DPS is conducted through a management process known as Capability Based Planning (CBP). CBP provides the tools through which the Defence Services Program can be linked to government policy and expectations [4]. Capability Based Planning is employed through a process that creates scenario specific force-wide Capability Goals. This begins with a forecast of the Future Security Environment (FSE) and subsequent examination of each scenario under the lens of the Future Security Environment and determines which capabilities and capacities will be required in the future. From an economics perspective, this process is a high level constrained optimization whose objective is to achieve optimal allocation of resources (maximize national security subject to fiscal constraints). CBP also explicitly encourages output-based planning by linking strategic goals to capability decisions. Thus focusing on forecasted future capabilities and the consequential effects, the tendency to simply upgrade existing systems can be avoided.

In addition to the assessment of the future security environment, CBP consists of two inter-related steps. Step 2 deals with the linkage of the Concept of Operations to the capability framework and to validate the planning process. In Step 3, an operations research technique is applied to create a priority list of relevant activities for the given force development scenario [6]. In general, CBP assists senior managers to establish Pan-CF priorities within the budget, and to shift resources among defence programs—and across the military services—from less to more productive uses in response to changes in the future security environment. Another economics interpretation of the CBP is linking future security environment and the policy intentions of political leaders, to decisions on force structure, readiness, and modernization. This problem is equivalent to choosing a point on a "production possibility frontier" that represents intertemporal trade-offs between "consumption" (current readiness) and "investment" (modernization or future readiness).

3.1 Utility Function

While CBP provides the general framework for the constrained optimization problem, the actual implementation of the plan, which is still under development, is the Capability Management process. The Capability Management process, will examine force options using a variety of tools and operational research to provide force development recommendations. In the interim, other tools have been used including one known as Capability Discussion Matrix (CapDiM) [2]. CapDiM prioritizes force options based on the preferences of decision makers on a set of criteria that reflect key aspects of either policy or CF strategic goals. In particular, force options are assessed against the DPS broad guidelines such as domestic and continental security as well as the vision and general guidance of the military principal often communicated in terms of general military attributes. Such military attributes include, for example, strategic lift, mobility, integration and interoperability (with allies). CapDiM subsequently will use these preferences as weights to prioritize the force options.

In essence these weighted values of preferences are military utility functions for the purposes of providing a subjective figure of merit or relative quality indicators of competing military capabilities in the CF. The CapDiM results have the key properties of a utility function in that it displays the ordering of force options. It is ordinal and the magnitudes are important as long as they assist in the ranking of the force options. By how much a force option is better than another does not add to one's understanding or description of the relevant decision maker's choice.

The utility function based on the force value option derived in Billyard et al [2] can be represented symbolically as:

$$U = U(F_1, ...F_n)$$
$$F_i = \sum_{j=1}^{M} \omega_j P_i^j \qquad (1)$$

The force options F_i are derived from Billyard [2] and are a weighted sum of a representative decision maker's preferences. Note that P^j_i is the preference (score) of the i^{th} force option rated against the jth criterion while ω_j is the weight of the j^{th} criterion and M is the number of criteria within a category. Billyard [2] also employ a more robust weighting scheme to ensure transitive and logical ordering of preferences.

3.2 Outputs and Other Issues

The use of utility functions is intuitively appealing especially in the absence of a quantifiable defence output measure. Measuring defence outputs are notoriously difficult. Economics and operations research articles often utilize military activity as an output proxy. For example, Hildebrandt [11] suggests sorties flown or for specific missions, such as interdiction, one can use reduction in throughput (see also [10]). Certainly DND produces intermediate outputs such as common and environment-specific training that have easily quantifiable outputs such as annual graduates. However, at the strategic level the relevance of capabilities to policy maybe the preferred output proxy.

While the emphasis on capabilities does force DND to focus on outputs instead of inputs, the translation of policy directives into measurable outputs is not without challenges. For example, the policy statement that Canada will defend the North American continent in cooperation with the United States may imply a number of capabilities. Is it exclusively the provision of Tactical Fighters or is it interoperability with US forces? How quickly could the CF provide an effective fighting force for a continental operation?

In addition, capabilities such as Light Infantry battalions or strategic lift may be appropriate outputs to DND but not necessarily to the decision-makers in the federal Cabinet. From a policy output perspective, the Cabinet may be interested in the combination of capabilities that can be deployed to an international *hot spot*. In essence, a single asset of strategic lift and battalion of light infantry troops will be the desired capability.

The services as force generators (trained and equipped soldiers) generate intermediate outputs while the commanders that actually deploy the soldiers utilize these intermediate outputs to conduct military operations and prevail in time of conflict [16]. We can surmise that the services (Army, Navy, and Air Force) are monopoly organizations relying on rule-based decision-making resembling command economies. Since there are no competing organizations that can provide maritime, land and air effects, there are no incentives to innovate or conduct efficiency improvements. In addition, there are no profit incentives that can entice each environment to continuously search for productivity improvements. Although not explicitly incorporated into CBP, a mechanism can be adopted to develop Pan CF from the start to eliminate the sub-optimal environment specific strategy.

There is an implicit assumption that the unit cost of military equipment would reflect the benefits (B) that are provided over the asset's service life. Thus, if a discount rate r captures the time value of money then the marginal rate over the life of the equipment equal to:

$$B\sum_{t=1}^{n} 1/(1+r+\delta)^{t} \tag{2}$$

note also that a constant depreciation rate of δ is also included in the benefit calculation. Setting the above expression equal to 1 and solving for the annual stream of benefits equals:

$$B=\frac{1}{\sum_{t=1}^{n} 1/(1+r+\delta)^{t}} \tag{3}$$

Given the implication inherent in accrual budgeting, r is set to zero in the model's case thus the benefit over the asset's life is governed by straight line depreciation. According to accrual budgeting DND is "paying back a loan" for the purchase of a platform as an annual amortized bill. There is no interest rate per se to pay back nor is there an accumulation of equity as DND pays back the loan. Chouinard and Wood [4] stress the fact that any model that estimates costs into the future must consider discount rates assuming one has a quantifiable and meaningful mechanism for discounting future benefits of defence capabilities. Thus for the purposes of

SCM, the EM inflation rates and a straight line depreciation of assets are the only mechanisms used to discount future benefits.

Another issue is that the Federal Government may institute policies and directives that may contribute little or no relevance to the main output/capability of DND. For example, a new accountability directive that increases resources devoted to auditing and reporting contributes little, if any, effect to military capabilities. In such cases, these directives add to the fixed/sunk costs of the DND.

Government-wide initiatives are sometimes necessary, if the central government wants to elicit a more cooperative response from government departments. This is a case most often articulated as the Principal-Agent problem in economics and it is often used to explain aspects of public sector administration. The Principal-Agent problem arises in a situation where a principal (Central government) compensates an agency (National Defence) for performing certain acts (defence policy) that are useful to the principal and costly to the agent, and where there are elements of the performance that are costly to observe. The key issue in this construct is the fact that it is either impossible or very expensive to monitor or understand the agents' performance and decisions. In addition, the incentives of the principal and the agent are often very different. This theory and the analytical studies that support it provide clues on how to design incentive policies to align the principal's goals to that of the agent.

The principal-agent problem can also be used to describe the challenges of resource optimization in a single government department. Melese et al [16] use examples from the US Department of Defense (DoD) to show how the Secretary of Defense and the Joint Chiefs of Staff as the principals face considerable challenge from the agents, each of the services, (Army, Navy, etc) who want to maximize service specific investment decisions. These service specific investment decisions tend to be sub-optimal and tend to frustrate the global optimization concerns of the principals.

4 SCM Methodology and Data

In this section the underlying methodology and data of the SCM is presented. The key feature of the model is the attribution of the intermediate military outputs such as training, infrastructure support and research and development (R&D) to military capabilities such as Strategic Lift and Light Infantry Battalions. Since the model is also looking at future force structure (30-year horizon) the articulation of risks, technology and discount rates need to be addressed. The sub-section (4.2) devoted to contingencies discusses how these factors are addressed in the SCM. The impact of government policies, the unique market structures of defence firms and other exogenous factors on future costs are also addressed in this section.

4.1 Data Sources

The sources of data for the model were in general, the DND financial information system (Financial and Managerial Accounting System-FMAS) and tools developed in DND namely the DPM (DND Personnel and O&M model), for personnel and O&M expenditures for existing force structure units and other departmental organisations; the Capability Investment and national procurement (NP) databases, for information on future capital projects, as well as future projections for spares and maintenance funds; and the funding supply database for Vote 10 funds (i.e. grants and contributions); and projected funding for the next 20-years.

The data was aggregated to a manageable degree by organizing it into over 300 Departmental cost centers and 400 capital and infrastructure projects. Subsequent versions of the model included additional items to correspond with the estimated costs of the Canada First Defence Strategy (CFDS) requirements. The earlier version of the model contained about 1300 cost items projected over 30 years to account for the capital and infrastructure replacement cycles for key systems. To the extent possible, actual asset life-times were used to project likely mid-life upgrade and eventual replacements. In the absence of actual life-time data, standard estimates such as 35 years for major naval assets, 40 years for realty assets and 20-30 years for different classes of air assets were used.

All intermediate outputs such as those associated with base, training and equipment support were attributed to cost centers more closely associated with the organizational elements from which operational force elements are drawn. This was accomplished by attributing the affected cost in proportion to an appropriate cost related measure of the asset's utilization of the intermediate asset. The attribution process is discussed in detail later in this section.

Almost all capital as well as spares and maintenance costs were used without modification in the earlier versions of the model. However, spares and maintenance data for newer fleet were re-calculated based on a multiplier factor developed within the Materiel group in DND[3]. This multiplier is based on the most recent data on in-service cost for aircraft and naval assets as well as data from allied nations with similar assets. As mentioned earlier, data on personnel costs and general operations and maintenance data (O&M) were extracted from the DPM. Personnel costs tend to be current in that they are based on recent compensation and human resources policies as

[3] The Comptroller shop in ADM Mat provided the multipliers. A formal study is underway.

well as on the latest personnel levels. However, the DPM is a cost recovery tool and as such tends to smooth activity based costs over time. Specifically, the O&M costs in the DPM were based on 5 year averages adjusted for inflation. As pointed out in the first volume of the SCM [4], the reality for DND has been a significant increase in O&M cost in real terms and as such the SCM baseline had to be adjusted using the ratio between the current year's budget for O&M and the DPM estimate of O&M costs.

4.2 Contingencies and Escalation Factors

Under the generic heading of contingencies, the earlier versions of the SCM included contingency values for the cost of specific platforms anticipated to be purchased based on policy statements and government announcements. Since these platforms were conceptual in a number of instances, the costs were based on a combination of bottom up approach (costing sub components) and a general premium of up to 30% for unobserved factors. While there are, as former US Secretary of Defense Donald Rumsfeld noted, "known unknowns and unknown unknowns", subsequent versions of the cost model attempted to formalize the treatment of inflation, defence specific factors (known unknowns), and technological impacts (unknown unknowns). These modifications are discussed below.

4.2.1 Defence Specific Inflation and Factors

There is considerable debate in the defence economics literature on the existence of "defence-specific inflation". A number of nations such as Australia, Israel, US and UK provide a separate inflation index for defence goods and services. A recent study [22] discusses the notion of defence-specific inflation (DSI) from a Canadian perspective and provides a cogent summary of the pertinent issues.

Since 1973, the Department of National Defence (DND) measured the impact of inflation on its purchasing power through a price trend forecast model (also known as the Economic Model (EM) and a price index for defence goods. Although the Department of Finance (DoF) never explicitly acknowledged the existence of DSI, it did fund DND based on the EM or a combination of GDP deflator plus a "growth" element. After discontinuing the extra funding during the budget cuts of the 1990s, the Treasury Board Secretariat (TBS) began funding the baseline less statutory at a nominal 1.5% rate annually since 1999 [22].

The rationale for the EM and the justification for calculating defence-specific inflation can be summarized as follows:

1. A unique relationship between a single buyer (monopsony) and few sellers (oligopoly);
2. The defence basket is different from the baskets underlying any other aggregate measure of inflation such as the Consumer Price Index.
3. Government restrictions regarding domestic content and national security requirements;

4. Rent-seeking behaviour by defence industries and others using military spending as an economic policy instrument (keeping expensive bases and weapon systems to promote regions and industrial sectors);
5. Decreasing-returns-to-scale in technology that may contribute to an inflation rate different from the general economy [22]; and
6. Exchange rate fluctuations will have greater effect on defence, as defence is the direct final consumer, and as such is also susceptible to importing inflation whereas in the economy, other factors tend to dampen the price level effects of exchange rate fluctuations (for DND guidance on the forecasting of inflation see [7]).

The question remains on whether the above mentioned factors contribute to inflation. Specifically critiques of DSI argue that:

1. The observed difference between DND's price index and the economy wide GDP are due to methodological and operational differences; as such the GDP deflator should adequately measure the variation in defence prices.
2. Defence inflation is a short-term phenomenon.
3. The unique market structure that governs defence acquisition causes relatively higher price levels as opposed to relatively higher inflation rates.

According to Solomon [22], the first argument rests on the concept of substitution effects. Consumers tend to switch to cheaper but similar goods when prices increase. Since most price indices are based on a basket of goods and prices of a fixed year, the impact of substitution is not captured. Fortunately, both the GDP deflator and the DSI are chained (the basket of goods are updated annually) and thus account for this substitution effect. Compared to the CPI index, which is not yet chained, the higher DSI inflation rate is very indicative since the chained DSI deflator produced systematically lower estimates of inflation. However, the DND-EM is designed to forecast price trends as opposed to producing a DSI index and consequently lacks historically linked time-series. Transferring this responsibility to Statistics Canada to produce a defence price index is a preferred alternative.

The second argument, the contention that defence inflation is a short-term phenomenon, was considered weak since the convergence between the various indices and the defence deflator was illusionary brought on by short-term impact of the severe defence budget cuts and the consequent reaction by DND to reduce capital acquisition plans and freeze wages. In addition, response to short-term price shocks as a result of input price changes (such as fuel, exchange rate, etc.) is immediate, and more persistent in defence relative to the general economy partially due to the different weights assigned to commodities and to some extent as a result of operational imperatives. For example, DND cannot reduce activity levels for ships and fighter aircraft as readily as a consumer or a firm making supply-side shocks persistent [22].

Solomon [22] was less than convinced on the third argument that defence may have high price levels but not high inflation. Solomon [22] used evidence from very small sample of defence capital projects in Canada to show that during the life of capital acquisition process, the inflation rate remained persistently high and different from the rate observed in the overall economy. This was due to offset arrangements and other policies, as well as exchange rates and foreign inflation.

Both the DSI and the economy-wide deflators have yet to account accurately the gains from productivity and quality improvements in the overall calculation of the inflation rate. Although the quality adjustment method used in the EM model discounts some equipment costs as quality related price pressures, there is a potential to overstate price increases to products characterized by rapid technological improvements, like military products. It should also be pointed out that quality improvements can be overstated as well, in particular cases where the products are sold in very competitive markets. Examples in the civilian market include sports equipment, etc.

Measurement problems also exist for indicators of personnel-related inflation. Gains from productivity need to be incorporated when analyzing the cost of personnel compensation. However, the productivity measure itself is prone to errors especially in areas of more abstract public goods such as national defence. Without a clear output indicator, the measurement of productivity is an approximation at best.

The SCM uses the forecasted inflation rates from the EM to account for inflation or price change forecasts for the current fiscal year plus 5 additional years.[4] Since the SCM is a 30-Year projection, inflation rates from the 5th year on wards are fixed.

General Ledger Accounts (small aggregation of goods and services that can be matched to National Accounts commodity structures) are used to determine DND's consumption basket. They constitute the smallest unit for which inflation forecasts are reported. Their relative weight is determined using the following formula:

$$q_{0i} = \frac{GL_{it}}{\sum_i GL_{it}} \tag{4}$$

That is, for each General Ledger (GL) Code, the weight q_{0i} is the proportion of the GL to the total defence expenditure for the last fiscal year denoted by i. Since the basket content is changed every year, the EM price index is a chained Laspeyres index [22].

The EM deflator implicitly incorporates quality changes by adopting quality-adjusted price indices for most defence goods and services that are also used by the civilian sector. The method used by Statistics Canada, and implicitly incorporated in the EM, is primarily *the consultation process*. This is a variant of the Performance/Cost of production process and incorporates detailed cost information to assess cost of producing the quality change. For the uniquely defence goods and services, however, quality adjustments have been made in an ad-hoc manner. For example, when a new weapons system replaces an old weapons system, the EM adopts a procedure of treating the new product as a quality adjustment to the old product. The procedure

4 For out years (t+5+), a composite number derived from a weighted average of the five forecast years (price changes Y) is given.

$Y_{t+5+} = 0.5Y_{t+1} + 0.1Y_{t+2} + 0.1Y_{t+2} + 0.1Y_{t+3} + 0.1Y_{t+4} + 0.1Y_{t+5}$ where t represents current fiscal year looks at physical differences and the cost of producing those physical changes is defined as the value of the changes [22].

The inflation rates are forecasted using univariate or multivariate forecasting model that uses the past history of the commodity as well as sector specific explanatory variables. Foreign inflation forecasts are based on information from private forecasting firms such as Global Insight (USA) and the Organization for Economic Co-operation and Development (OECD). Finally foreign currency fluctuations are estimated and forecasted using standard models such as the Bank of Canada model or a Random Walk specification (see for example [18] and [25]).

In most instances, there is a lack of theory-based econometric specification (a regression relationship correlating domestic inflation to socio-economic factors) and therefore univariate time-series models are used to forecast inflation rates. In particular, the univariate Box-Jenkins (B-J) [3] is a time-series modeling process, which describes a single series as a function of its own past values. The purpose of the B-J process is to find the equation (or filter) that reduces a time-series with underlying structure to white noise. Since the filter accounts for the predictable portion of the time-series, it can be used to forecast future values of the series. Symbolically,

$$\phi_p(B)\Phi_P(B^s)\nabla^d {\nabla^D}_s Z_t = \theta_q(B)\Theta_Q(B^s)a_t \tag{5}$$

Where *s* denotes periodicity of the seasonal component (i.e. 4 for quarterly and 12 for monthly); B denotes the backward operator ($BZ_t=Z_{t-1}$ and $B^sZ_t=Z_{t-s}$); $\nabla^d=(1-B)^d$ is the difference operator of order d; $\phi_p(B)$ and $\Phi_P(B^s)$ are stationary autoregressive operators (they are polynomials in B of degree p and in B^s of degree P, respectively); $\theta_q(B)$and $\Theta_Q(B^s)$ are invertible moving average operators and a_t is a purely random process. These models are also known as AutoRegressive Integrated Moving Average or ARIMA.

The forecasting strengths of the models are often assessed using the usual battery of tests including the Mean Absolute Percentage Error (MAPE) and variants such as the Root Means Square and the Mean Square percentage errors. In addition Theil's Inequality Coefficient [26] is also calculated to compare the forecasting models to simple naïve forecasting methods.

As mentioned above, the forecasting of major macro economic variables as well as foreign wages and CPI are contracted out to private forecasting and economic consulting firms. In terms of the in-house forecasts, the trend has been towards large-volume batch forecasting of the defence goods via automated Box-Jenkins methods. While these types of models continue to be popular among private and public institutions, recent studies show the quality of the forecasts are not as impressive as expected [14]. While the economics unit within DND (ADM Finance and Corporate Services) has been actively monitoring advances in time-series econometrics, these latest models have yet to be formally integrated into the forecasting process.

Foreign currency fluctuations are forecasted using a variant of a Random Walk model for the short-term and an econometric model mimicking the Bank of Canada model for the long-term.

This long-term model tends to use, among others, interest rate differential, fiscal trends and commodity prices to predict the Canadian dollar fluctuations against its U.S. counterpart. Given the fact that approximately 10% of DND's expenditures are in foreign currencies, other divisions within DND have developed models to mitigate foreign exchange risks. The FOREX model [8] is one such model that uses the theory and methodology behind the Value at Risk (VaR) model to asses the maximum expected loss from foreign exchange exposure over a given budget year.

For the purposes of the SCM, the forecasted inflation rates are aggregated to match the cost types (military and civilian pay, O&M, NP, capital) to perform the transformation from constant dollar (CY) to budget year dollar BY (account for inflation).

$$CY_i \prod_{i=1}^{n} (1 + p_{di}) = BY_i \qquad (6)$$

Note that p_{di} is the inflation rate for the i^{th} cost item.

4.2.2 Policy Based Cost Escalation

Against the backdrop of a declining defence budget as part of the GDP, limited domestic demand for military goods and services and to counter an alleged array of policy instruments used by other nations with whom Canada competes (Brazil, European Union, etc) in the defence industrial sector, the Federal government actively supported an industrial offset policy and its later incarnation, the industrial regional benefit (IRB) program for its aerospace and defence sectors. Industrial offsets are contracts placed in Canada by foreign companies to offset the loss of jobs or other economic benefits to Canada as a result of the external procurement of major defence equipment [5]. These offsets are usually a large percentage of the total dollar value of the original contract (50-100%). Prior to 1985, there was no explicit provision to distribute benefits regionally. Offsets are a distinctive feature of Canadian defence procurement policy.

The efficacy of IRB programs has been examined with the conclusion that the benefits are at best marginal [23], [20] and [28]. Specifically:

1. Regional distribution of the IRB benefits mirrors the existing defence industrial structure with Ontario's share of defence production declining while Quebec's share is increasing. To a large extent the consolidation of the aerospace sector explains the relative changes in Quebec and Ontario rather than specific government policy.
2. Even if this shift from Ontario to other regions is a result of the offsets/IRB, this may be counter productive since it may hinder companies from capturing the synergistic benefits of the clustering of defence related activity facilitating horizontal or vertical integration within a limited geographical region with it attendant efficiency benefits. In other words, established regional clusters may be hurt by movement of work to other regions, making the sector as a whole less competitive.

3. The IRB policy is seen as necessary to the defence industrial base as Canada imports more than it exports [9]. Solomon's [20] data showed that in the last 15 years the trend toward import dependence has accelerated.

Also note that there may be other more efficient policy tools that can bring about regional benefits. For example, New Brunswick, one of the Atlantic Provinces, has successfully brought major communications and Information Technology (IT) sector activity to its province with a combination of tax incentives and well-established infrastructure including a bilingual educated work force. Again there are competing policy tools that can provide similar benefits and IRB may not be suitable to some regions or sectors. In particular the IRB's stated goal of maximizing benefits flowing to a region "facing particularly difficult economic circumstances" may be futile if the necessary tax base or infrastructure is not in place to exploit the benefits flowing from a large procurement.

Regardless, such policies exacerbate the defence management problem as defence management tries to invest/divest capabilities from a purely military and future security environment perspective. The more these policies play a role, the less the Department can focus its choices that optimize overall defence program efficiency. Most importantly, Solomon [20] found that the premium imposed by industries for administering policies such as IRB ranged from 13-22%. Consequently, for the purposes of the SCM, the impact of IRB type policies was incorporated to generate contingency rates.

In terms of the "unknown unknowns" Kirkpatrick [13] has found that equipment costs have been rising by about 10% per year in real terms and the rising unit production costs is similar and tend to exhibit the same characteristics as individuals and corporations that compete with each other such as sporting equipment, fund managers, sports personalities, etc. In addition, the inflation rates generated from the EM tend to based on DND's current expenditures, the forecasted rates do not account for the likely defence specific inflation rates that may be likely in the post defence policy equipment modernization phase. Until such time that the data will be updated on actual and reasonable cost estimates, the Solomon [20] historical inflation rates for selected air force platforms are used as a proxy for the unknown technology-based cost escalation.[5]

4.3 Attribution Rules and Technology Coefficients

The attribution rules are based on an instrumental variable concept in that the "attribution rule" problem is to identify not the specific cost drivers for each detailed service but indicators (akin to econometrics) of "usage" for broad indirect cost groups. As pointed out in the first volume of the SCM [4] the attribution rule should be transparent and replicable to all "users" of the indirect cost group's service. These instruments are not the cost drivers or a metric for activity rates such as sea days or Yearly Flying Rates (YFR). These instruments include the *number of people* for training and personnel support, *equipment operating costs* for maintenance and overhaul, and p*ersonnel and O&M costs* for total demand such as base support.

[5] These rates were in excess of 20% and included platforms such the AURORA and CF-18.

Equipment operating cost is a better proxy in the SCM for allocating equipment support costs as opposed to the number of equipments allocated to a unit since maintenance and sparing is going to depend on usage as well as costs of supplies, labour, etc. Similarly, bases host training, equipment support and operational support units. The total cost of a base includes direct personnel and operations and maintenance costs as well as attributed portions of the national total of base communications, health services and personnel support services. Base cost was attributed in proportion to the sum of its lodger unit's personnel and O&M cost.

The specific mechanism for assigning the cost of intermediate outputs (enabling elements such as training and personnel support) is illustrated below (Table 4). For example, naval training is an intermediate output consisting of assets such as Maritime Warfare Centre, the ship HMCS Oriole, Naval Schools and sea training. The civilian and military personnel that work in each of these organizations as well as their O&M costs make up the total cost of naval training. Thus, in 2008, the total cost is estimated to be $251M in constant year dollars. There are a number of final maritime capabilities such as destroyers, frigates and fleet headquarters that use naval training. The attribution of this training activity is based on the proportion of personnel each of the maritime capabilities will potentially use the training. This proportion is based on the total cost of personnel in each of these final capabilities in the reference year. Thus for frigates, the people costs in the reference year was $ 232M or 49% of the total of all naval capabilities that used naval training.

The attribution rules generate, in input-output model parlance, technology coefficients that are updated annually but the 30-year view remains fixed on these updated technology coefficients. To the extent the modeller receives a-priori information about a new in-service support arrangement or training that may affect the attribution of training, material and infrastructure support, etc., these will be incorporated in the 30-year projection. An example of such "early warning" data is the in service support arrangements for the strategic-lift capability.

Other indirect costs shown on the table refer to base support that may call up other intermediate outputs. Certain attribution classes are absorbing in that once a cost component contributes to that class, it does not propagate further. The remaining classes are *transitory* in that all the costs in the class are allocated to other classes. From this perspective the attribution process can be conceived of as a single stage of an elementary Markov process, a well known mathematical structure of wide application.

One of the consequences of the Markov theory is that, for the situation described, one can derive a matrix which serves to attribute all costs, operational item and enabling item, to the end items within a finite number of steps. By first calculating this matrix, summing the direct costs within each attribution class and applying appropriate cost escalation factors, the total operational item cost could be determined immediately.

Table 4: Naval Training Attribution Example ($000)

Training Asset	Cost Type (CY$)	2008	2015	2020	2025	2034
Maritime Warfare (MW)	O&M	$ 369	$ 369	$ 369	$ 369	$ 369
MW - Civ Pay	Civ Pay	$ 681	$ 681	$ 681	$ 681	$ 681
MW - Mil Pay	Mil Pay	$ 6,166	$ 6,166	$ 6,166	$ 6,166	$ 6,166
HMCS Oriole	O&M	$ 721	$ 721	$ 721	$ 721	$ 721
HMCS Oriole - Mil Pay	Mil Pay	$ 502	$ 502	$ 502	$ 502	$ 502
Naval Schools	O&M	$ 10,939	$ 10,939	$ 10,939	$ 10,939	$ 10,939
Naval Schools - Civ Pay	Civ Pay	$ 5,886	$ 5,886	$ 5,886	$ 5,886	$ 5,886
Naval Schools - Mil Pay	Mil Pay	$ 142,408	$ 142,408	$ 142,408	$ 142,408	$ 142,408
Sea Training	O&M	$ 310	$ 310	$ 310	$ 310	$ 310
Sea Training - Civ Pay	Civ Pay	$ 44	$ 44	$ 44	$ 44	$ 44
Sea Training - Mil Pay	Mil Pay	$ 6,156	$ 6,156	$ 6,156	$ 6,156	$ 6,156
Navy Training-Sustainability	O&M	$ 9,014	$ 9,238	$ 9,238	$ 9,238	$ 9,238
Other Indirect Costs	Full	$ 68,233	$ 68,233	$ 68,233	$ 68,233	$ 68,233
Total		**$ 251,428**	**$253,668**	**$253,673**	**$253,678**	**$253,687**

Asset	Military Personnel Costs ($000)	Attribution %	2008	2015	2020	2025
Fleet HQ	$ 8,522	1.8%	$ 4,496	$ 4,403	$ 4,338	$ 4,464
Destroyers	$ 69,190	14.5%	$ 36,506	$ 35,749	$ 35,218	$ 36,244
Frigates	$ 231,769	48.6%	$ 122,285	$ 119,751	$ 117,970	$ 121,409
Other Capabilities	$ 167,056	35.1%	$ 9,390	$ 9,196	$ 9,059	$ 9,323
Total	$ 476,537					

5 Applications and Some Results

In this section the discussion focuses on typical analyses that can be conducted using the SCM. As indicated in earlier sections, one of the main rationales for the SCM is its utility in providing cost/ benefit or risk analysis. For instance using the SCM, one can provide guidance on whether the mix of capabilities that the CF chooses to support is affordable and meets, to the best degree possible, the Government's response to the current and future security environment. Since the model can be reformulated as an input-output representation, some typical analysis on the requirement of inputs such as personnel or support can also be analyzed using the SCM rich data set.

The SCM also provides insights into force structure and related problems that require further investigation or scrutiny. Some of these findings are strategic such as the trends in equipment-to-personnel ratio while others look at operational and tactical level considerations such as the cost of training or the challenges facing the environments (Army, Navy and Air Force).

5.1 Marginal Cost-Benefit Analysis

As pointed out earlier, CBP is being institutionalized in DND and the results of the process will provide quantifiable measures of capability (outputs) benefits. For purposes of illustration we use hypothetical military utility figures that can be generated from interim models such as CapDiM to show a typical marginal cost-benefit analysis. Figure 2 provides such illustration for a selected number of military capabilities. For purposes of cost-benefit analysis at the margin, costs are measured in increments of deployable assets. For example when Canada participates in international or continental missions, it does not deploy its entire tactical fighter (CF-18) capability. It may only deploy six tactical fighters and a battalion of infantry. For the purposes of this illustration and future cost-benefit analysis the incremental cost of such deployable capabilities will be measured. For historical data on the mix of capabilities deployed in past missions, see Mason [15]. Note that the historical data were not used to generate the the hypothetical cost-benefit analysis depicted in Figure 2.

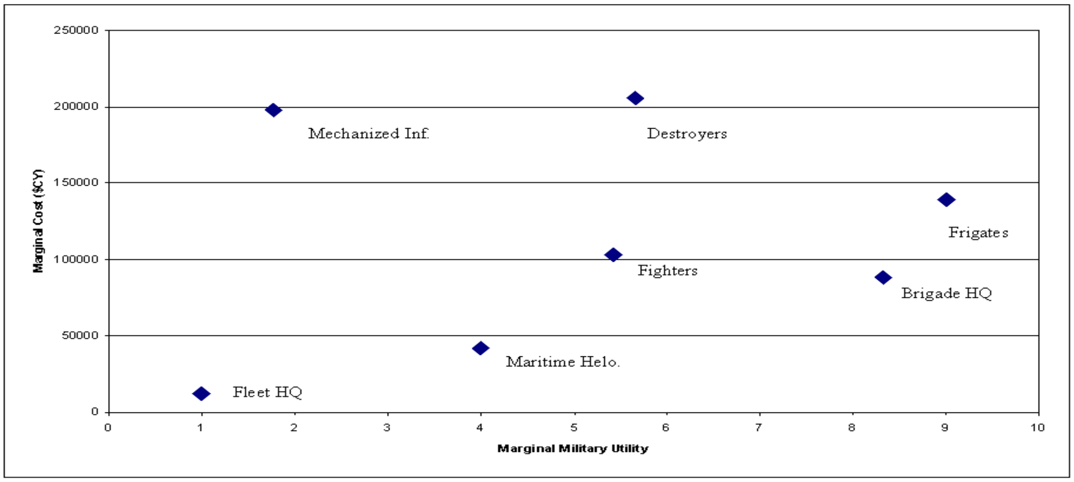

Figure 2: Hypothetical Cost-Benefit Analysis

According to Figure 2, the hypothetical military utility or benefits measure indicates that frigates and brigade headquarters are on the high end of utility while fleet headquarters and mechanized infantry are at the low end of the benefit spectrum. On the cost side, the marginal cost of a destroyer and a mechanized infantry are the expensive end while maritime helicopters and brigade headquarters are the cheapest to deploy in this selected group of capabilities. The combined benefit-cost analysis seems to favour the brigade headquarters, frigates and tactical fighters.

5.2 Input-Output Type Applications

There are a number of key similarities between the SCM and the design of an input-output (I-O) model. First, in both cases, the inputs required in the operation of each activity (military capability/effects) are either a primary input or an intermediate input. In the SCM, primary inputs are the direct costs such as civilian and military costs, equipment (capital), infrastructure and repair and overhaul. The indirect costs in SCM, such as research and development (R&D), common and environment-specific training and equipment, infrastructure and information support are considered intermediate inputs. These intermediate inputs are really outputs of some other defence activity.

Second, I-O models explicitly and the SCM somewhat implicitly assume that inputs are demanded in fixed proportion to their outputs. For example, if a single light infantry battalion requires 100 personnel and 100 small arms, then 5 battalions will require 500 of each equipment and personnel. Similarly, the labour-capital ratio is proportional.

Once again, using a select group of capabilities we illustrate the use of SCM to plan personnel requirement. According to Table 5 the naval capabilities of destroyers and frigates require 3 and 2 personnel indirectly or in support for every one that is directly employed. Fleet and Brigade headquarters require almost one indirect personnel (0.86) for every one directly employed. Similarly, there is a proportionate personnel requirement for the mechanized infantry (0.9). The air assets of maritime helicopters and tactical fighters have a higher "tooth to tail" ratio (higher indirect support) at 4 and 5 personnel for every direct employment. In all cases in Table 5, the high indirect personnel requirement stems from infrastructure and equipment support for the capabilities considered.

Table 5: Per Asset Personnel Requirement

Cost Types	**Destroyers**	**Frigates**	**Fleet HQ**	**Brigade HQ & Signals**	**Mechanized Infantry Battalions**	**Maritime Helo.**	**Tactical Fighter**	**NBC Defence Company**
Direct	143	225	56	287	612	17	9	141
Support	344	247	14	135	306	46	28	34
R&D	18	16	2	9	20	3	3	1
Training	134	148	32	99	224	21	12	15
Total Indirect	**496**	**411**	**48**	**243**	**550**	**70**	**43**	**50**
Ratio Indirect to direct	3.47	1.83	0.86	0.85	0.90	4.12	4.78	0.35

Note: Personnel include military, civilian and reserves. Support includes infrastructure and equipment.

A more detailed analysis can be conducted using a characterization of an I-O table. As can been seen from the tables in Annex A, the matrices provide a breakdown of the intermediate outputs such as infrastructure, personnel and equipment support and the inter-relationships to a select group of final outputs and capabilities.

5.3 Labour-Capital Ratios

There is no theoretical or empirical study that suggests an optimal capital-labour (military equivalent of equipment-personnel) ratio. Treddenick [27] developed a model based on simple additive principles of capital accumulation (additions of new equipment and deletions of militarily obsolescent equipment) to make projections on the likely capital-labour ratios for assumed inflation rates, manning levels, and capability goals. In essence, the Treddenick approach makes the capital-labour ratio the objective and given the budget, adjusts labour. Thus it may be possible to end up with very few soldiers; while the government gets the most capability out of the money it provides DND/CF.

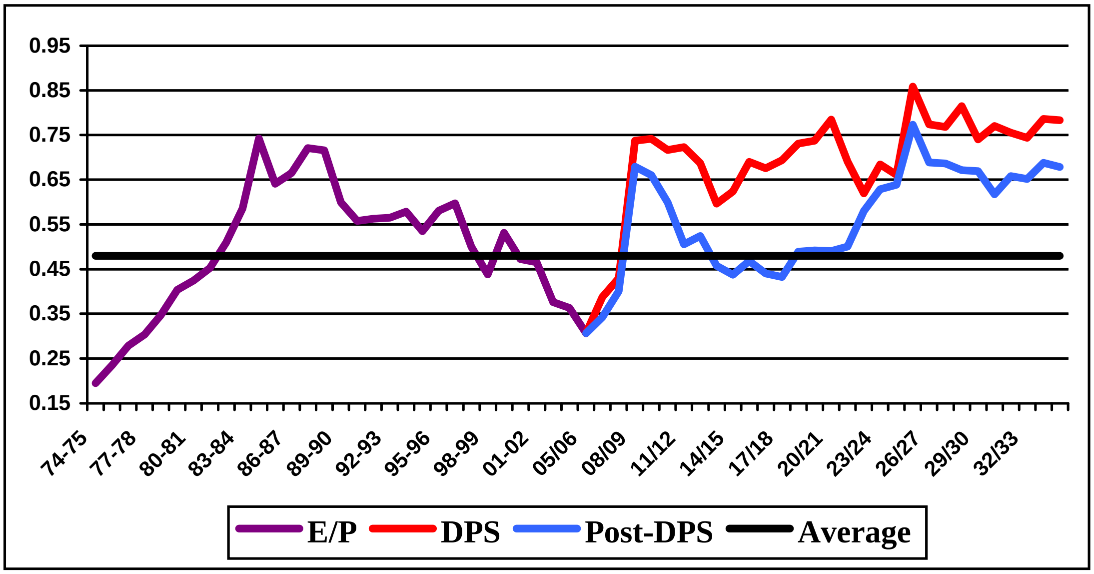

Figure 3: Equipment-Personnel Ratios (E/P historical, DPS Defence Policy Statement Post DPS-Budget 2006)

Figure 3 shows the likely equipment-to-personnel ratios that may be feasible in the next 30 years given the policy and platform initiatives imbedded in Budget 2005 and 2006 expenditures and capital investments. Note that the chart contrasts these ratios to past expenditures to show any significant divergence. For the purpose of comparisons, the capital addition is excluded from the past and future projections (only capital acquisition as opposed to acquisition, accumulation and deletion is considered).

The chart shows that the heavy investment in troop mobility and projection capability will make the CF more capital-intensive relative to its recent past. However, the Budget 2006 requirement to increase the Regular Force component of the CF to 75 thousand will reduce the capital intensity below its long-term average. This in itself may not be a problem especially as there is no theoretically/empirically acceptable ratio. However, there are some concerns worth noting if the capital-intensity maintains a downward trend.

First, as discussed earlier, equipment prices are rising while budgets are at best not growing at the same rate or worse kept static. This leads to higher O&M costs crowding out potential capital investment, leading to a declining share of the budget going to capital investment, either in the form of capability renewal or the adoption of transformational capabilities. This is a vicious cycle, leading to a reduced capacity to provide necessary or sustained capabilities.

Second, it is more important to decide upon the capital-labour ratio one is able to achieve and maintain as opposed to how much one spends on capital. The trend in the past 30-years, as depicted in Figure 3, shows that the ratio peaked in the mid 1980s and continued to decline even as the CF population was falling. The situation is expected to reverse after the capital acquisition decisions stated in Budgets 2005 and 2006 become reality in the coming 5-10 years.

While the discussion above stresses the problem associated with lower capital intensity, adjustments to military personnel also carry unique opportunities and challenges. Since the personnel costs account for approximately 50% of the DND/CF budget, any change in CF population will have immediate and long-term consequences. Recall that the CF declined steadily during the mid-1990s to a White Paper-mandated 60 thousand Regular Force members. While this helped the government's effort to combat the rising deficit, this hasty and significant downsizing of the CF resulted in the current *hollowing* of the cohort of military personnel with 8 to 16 years of experience. It is this particular cohort that is most often called on to conduct operations, to train a growing number of recruits, and to develop to become the future senior leaders of the CF as those inducted in preceding years retire.

5.4 Training Costs

The SCM can also provide insights about centrally managed projects/programs – specifically training. Given the limitations of current information systems, the answers to some important questions such as the cost of training a military member are not readily available. Although the SCM was not designed specifically to answer such operational-level questions, it can provide some insight into these questions with minimum amount of modification. Table 6 shows the departmental resources devoted to training for each of the environments. Overall the average cost of all training for the selected years is approximately $1.7 billion, with Common Training at about $700 million, Land Training at $500 million and Air and Sea Training at about $250 million each. These costs are in constant year dollars and exclude the effect of inflation.

Table 6: Estimated Total Training Costs (CY Dollars)

	2008	2010	2012	2015	2020
Common Training	$ 762,581	$ 718,982	$ 685,506	$ 680,764	$ 684,607
Naval Training	$ 251,428	$ 250,768	$ 249,299	$ 246,218	$ 242,557
Air Training	$ 247,238	$ 230,996	$ 227,475	$ 224,757	$ 222,388
Land Training	$ 530,850	$ 489,280	$ 473,204	$ 462,656	$ 471,792
Health Schools	$ 26,981	$ 26,981	$ 26,981	$ 26,981	$ 26,981

Common training is the most expensive. However, when adjusted for volume (personnel from all services are trained) it is relatively inexpensive. Similarly, the Army trains more personnel relative to both the Navy and the Air Force. Table 6 also reflects the impact of the Budget 2005 announced 3000-reserves and 5000-regular forces increase. Although not shown in Table 6 due to the selected timeframe, the SCM does include the impact of the additional personnel increase announced in Budget 2006.

The SCM can also provide a more refined analysis of training in DND by comparing the direct and indirect (overhead) costs associated with common and environment-specific schooling. Figure 4 shows that Common and Land components have 70% of their costs attributed directly. In contrast, direct Air Training accounts for 45% of the Air Training impact to the Department and in contrast to both, maritime training has the least overhead with 75% of its departmental impact showing up as direct costs.

Basic flying as well as rotary and multiple-engine training in Southport and Moose Jaw are currently conducted by the private sector with military instructors. This implies that the cost of equipment, operation and maintenance, training facilities, as well as day-to-day management is contracted out and shows up as indirect cost. All things being equal, the private sector should be able to provide services cheaper than the public sector. The main assumption here is that competition in the private sector fosters cost-effective operation and profit levels. Economic theory, however, is explicit in emphasizing the need for legitimate competition to induce efficiency gains in outsourcing. In addition, the active monitoring and proper accounting of oversight costs must be undertaken and explicitly included in the overall cost of outsourcing.

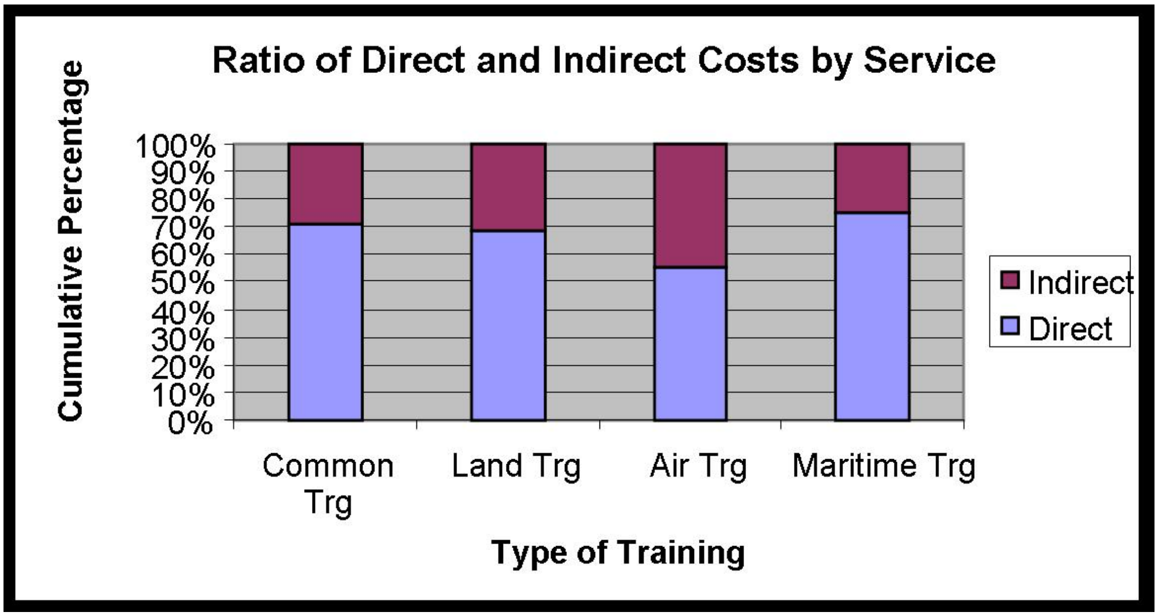

Figure 4: Estimates of Training Overhead

In essence, without a properly administered bidding process with a number of viable competitors, a company can easily outbid competitors in the first-round hoping to sole-source subsequent contract extensions. Once this monopoly position is achieved, the cost savings expected from outsourcing will be minimal, if any.

6 Conclusions and Future Directions

The allocation of scarce resources among alternative and competing demands is the central tenant of economics and it is also the case for both the Federal government and the Department of National Defence. The examination of the country's macroeconomic condition revealed that fiscal prospects have improved substantially since the mid-1990s. The tight fiscal restraints that brought the balanced budget, however, have hindered the efficient delivery of many public services including health and defence. In addition, the declining standard of living and the gap in productivity between Canada and its largest trade partner, the United States, are now the main policy topics crowding the ever-increasing demand for stable funding.

The optimal allocation of defence resources in a constraining budgetary and policy environment is a complex task. This activity is made all the more complicated due to dynamics and interdependencies among expenditure types and production technologies. One of the main strengths of the SCM is its ability to bring simplicity, clarity and needed order to the relationships that govern the constrained optimization problem. Once the Capability Based Planning process is fully institutionalized the benefit side of the equation will be clearer and the optimization problem more transparent.

While not explicitly discussed in the preceding sections, the model can generate results that can shape future force development strategies. Can the army exploit synergies by focusing on light infantry, special operations and related rapid response functions and transferring some of its more capital intensive capabilities over to Reserve units? Are there government agencies that can conduct some capabilities such as territorial surveillance?

As pointed out in the first volume in the series, all models do violence to reality and the SCM is no exception. In addition to model enhancements discussed in Volume I, this volume also makes suggestions for future research in subsequent sections with particular focus on empirical extensions.

While the SCM implicitly recognizes the existence of the unique production function and technology that characterizes each environment, it is not disaggregated. A promising avenue for further research is the interpretation of the SCM as an Input-Output structure in order to exploit the interrelationship among the environments and their respective inputs and outputs.

The SCM recognizes the heterogeneity of the capital assets but makes adjustments for the differing life spans only and needs to make allowances for the difference in the rate of depreciation. There are two-avenues for further research in the area of personnel. First, the regular and reserve forces are aggregated in the SCM limiting important analysis on the possible tradeoffs between these forces and the production of defence capability. Second, military personnel can be considered as human capital or additions to inventory to be drawn as required for various operations. Within an inter-temporal modeling perspective human capital will be treated as fixed in the short-run and variable in the long run.

Finally, future extensions to the model should entertain ways and means of estimating total factor (capital and labour) or labour productivity measures for the military in aggregate and subsequently in disaggregate form for each environment.

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Annex A Input-Output Tables and Matricies

Table A-7: Primary and Intermediate Outputs Shares for Selected Capabilities

	Wm	Wc	O	Ke	Ks
Destroyers					
Direct	0.367	0.000	0.801	0.991	0.814
Support	0.344	0.844	0.118	0.008	0.185
R&D	0.002	0.071	0.024	0.000	0.000
Training	0.288	0.086	0.057	0.002	0.001
Frigates					
Direct	0.500	0.000	0.671	0.985	0.757
Support	0.222	0.792	0.180	0.012	0.241
R&D	0.002	0.081	0.037	0.000	0.000
Training	0.277	0.126	0.113	0.003	0.002
Fleet HQ					
Direct	0.609	0.180	0.352	0.000	0.000
Support	0.081	0.387	0.294	0.649	0.818
R&D	0.001	0.126	0.060	0.000	0.000
Training	0.308	0.308	0.294	0.351	0.182
Brigade HQ & Signals					
Direct	0.630	0.104	0.747	0.849	0.654
Indirect	0.370	0.896	0.253	0.151	0.346
Support	0.189	0.583	0.072	0.081	0.325
R&D	0.001	0.098	0.046	0.000	0.000
Training	0.181	0.216	0.135	0.070	0.020
Mechanized Infantry Battalions					
Direct	0.621	0.003	0.685	0.912	0.616
Indirect	0.379	0.997	0.315	0.088	0.384
Support	0.195	0.642	0.073	0.048	0.363
R&D	0.001	0.108	0.060	0.000	0.000
Training	0.183	0.247	0.181	0.041	0.021
Tactical Fighter					
Direct	0.224	0.002	0.331	0.976	0.788
Indirect	0.776	0.998	0.669	0.024	0.212
Support	0.515	0.627	0.122	0.021	0.211
R&D	0.002	0.228	0.051	0.000	0.000
Training	0.258	0.144	0.496	0.003	0.001
Maritime Helo					
Direct	0.239	0.007	0.261	0.948	0.811
Indirect	0.761	0.993	0.739	0.052	0.189
Support	0.493	0.671	0.249	0.039	0.186
R&D	0.002	0.149	0.052	0.000	0.000
Training	0.266	0.173	0.438	0.013	0.002

NBC Defence Company					
	Wm	Wc	O	Ke	Ks
Indirect	0.202	0.952	0.408	0.014	0.125
InfraSupport	0.137	0.642	0.330	0.013	0.119
R&D	0.000	0.088	0.018	0.000	0.000
Training	0.065	0.223	0.059	0.001	0.006

(Table A-7 Concluded)

Table A-8: Sample I-O Representation with Technology Coefficients

Selected Final Outputs (Capabilities)	Housing Agency	Health Svcs	Med Sp & Trg	Person nel Spt	Comms Spt	Infras - Air	Base - Navy	Infras - Land	Base - Air Tpt	Base - MPA	Base - Air Trg
National Defence HQ	0.05	0.05	0.04	0.07	0.06	0.00	0.00	0.01	0.00	0.00	0.00
Fleet HQ	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Destroyers	0.03	0.03	0.03	0.03	0.03	0.00	0.15	0.00	0.00	0.00	0.00
Frigates	0.08	0.08	0.07	0.08	0.08	0.00	0.39	0.01	0.00	0.00	0.00
Coastal Defence	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.00	0.00	0.00
Brigade HQ & Signals	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.04	0.00	0.00	0.00
Mechanized Infantry Battalions	0.08	0.07	0.06	0.06	0.06	0.03	0.00	0.15	0.09	0.00	0.00
Light Infantry Battalions	0.03	0.03	0.02	0.02	0.02	0.00	0.00	0.06	0.00	0.00	0.00
Armoured Reconnaissance Regiments	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.05	0.00	0.00	0.00
Combat Engineer Regiments	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.04	0.00	0.00	0.00
Engineer Support Regiment	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00
Combat Service Support	0.04	0.04	0.04	0.04	0.03	0.00	0.00	0.10	0.00	0.00	0.00
Maritime Helo	0.03	0.03	0.02	0.03	0.03	0.01	0.11	0.00	0.01	0.00	0.08
SAR Helo	0.01	0.01	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.07	0.01
Tactical Fighter	0.06	0.05	0.05	0.05	0.07	0.24	0.00	0.01	0.01	0.00	0.10
Radar Squadrons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deployable Air Ops Support	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01
National Support Formation	0.03	0.02	0.02	0.02	0.02	0.00	0.00	0.06	0.00	0.00	0.00
Joint Signals Regiment	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00
CF Field Hospital	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
CF Force Protection - Military Police	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ranger Patrol Groups	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
National Level Service Delivery	0.02	0.02	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00

Table A-9: Sample I-O Representation with Technology Coefficients Continued

Selected Final Outputs (Capabilities)	Land Minor Capital	Land - Inf	Land - ISTAR	Maritime Equip	Maritime Equip Major	Maritime Equip Minor	ASG / LTEU	ADAC	CF METR	CORA	DRDC Atlantic	DRDC Ottawa	DRDC Toronto
National Defence HQ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.02
Fleet HQ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Destroyers	0.00	0.00	0.00	0.21	0.29	0.21	0.00	0.21	0.18	0.04	0.15	0.04	0.05
Frigates	0.00	0.00	0.00	0.40	0.57	0.40	0.00	0.55	0.36	0.10	0.36	0.10	0.12
Coastal Defence	0.00	0.00	0.00	0.08	0.00	0.08	0.00	0.00	0.00	0.01	0.03	0.01	0.01
Brigade HQ & Signals	0.05	0.00	0.22	0.00	0.00	0.00	0.05	0.00	0.00	0.02	0.00	0.02	0.01
Mechanized Infantry Battalions	0.20	0.73	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.08	0.00	0.07	0.05
Light Infantry Battalions	0.08	0.27	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.03	0.00	0.03	0.02
Armoured Reconnaissance Regiments	0.07	0.00	0.36	0.00	0.00	0.00	0.07	0.00	0.00	0.03	0.00	0.02	0.02
Combat Engineer Regiments	0.06	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.02	0.00	0.02	0.01
Engineer Support Regiment	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.00
Combat Service Support	0.12	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.05	0.00	0.04	0.03
Maritime Helo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.04	0.12	0.04	0.04
SAR Helo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tactical Fighter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.07	0.19	0.22
Radar Squadrons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deployable Air Ops Support	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
National Support Formation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01
Joint Signals Regiment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
CF Field Hospital	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CF Force Protection - Military Police	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ranger Patrol Groups	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
National Level Service Delivery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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List of symbols/abbreviations/acronyms/initialisms

ARIMA	Autoregressive Integrated Moving Average
B-J	Box-Jenkins
BY	Budget Year (dollars)
CapDim	Capability Discussion Matrix
CBP	Capability Based planning
CF	Canadian Forces
CFDS	Canada First Defence Strategy
Civ Pay	Civilian Personnel Pay (wages and associated costs)
CORA	Centre for Operational Research and Analysis
CPI	Consumer Price Index
CY	Constant Year (dollars)
DCP	Defence Capability Plan
DFPPC	Director Force Planning and Program Coordination
DND	Department of National Defence
DoD	Department of Defense (United States)
DoF	Department of Finance (Canada)
DPS	Defence Policy Statement
DRDC	Defence Research & Development Canada
DRI	Data Resources Inc
DSFC	Director Strategic Finance and Costing
DSI	Defence Specific Inflation
E/P	Equipment/Personnel (ratio)
ECM	Error Correction Model
EM	Economic Model
FMAS	Financial Managerial Accounting System
DPM	DND Personnel and Operations and Maintenance Model
FSE	Future Security Environment
FY	Fiscal Year
G7	Group of Seven (Industrialized Nations)
GDP	Gross Domestic Product

GL	General Ledger
IMF	International Monetary Fund
I-O	Input-Output
IRB	Industrial Regional Benefit
IT	Information Technology
MAPE	Mean Absolute Percentage Error
Mil Pay	Military Pay (wages and associated costs)
MW	Maritime Warfare
NP	National Procurement (spares)
O&M	Operations and Maintenance
OECD	Organization for Economic Cooperation and Development
PDI	Personal Disposable Income
PI	Personal Income
R&D	Research & Development
SCM	Strategic Cost Model
TBS	Treasury Board Secretariat
US	United States
VAR	Vector Auto Regression
VaR	Value at Risk
YFR	Yearly Flying Rate

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The production of defence capabilities is based on the principles of constrained maximization. That is, it is a process that maximizes the military capability achievable from a given budget with a given defence technology and a given set of input prices. The first step in this process is to develop a model or a process that can estimate the total cost of producing military capabilities. This paper discusses such a model, developed in Defence R&D Canada, with particular emphasis on the economics and operational research methodologies underpinning the modeling framework. From an economics perspective the model is a hybrid of a multi-product or joint output production function and a simplified Input-Output model. A number of simulations are conducted and the paper highlights some of the strategic level results and their associated implications on the Canadian Forces and the Defence Capability Planning process.

La production des capacités de défense repose sur les principes de l'optimisation restreinte, c'est-à-dire un processus qui maximise la capacité militaire réalisable à partir d'un budget donné, d'une technologie de défense donnée et d'une série donnée de prix à l'entrée. La première étape du processus consiste à élaborer un modèle ou un procédé permettant d'estimer le coût total de la création de capacités militaires. Cette communication présente un modèle de ce type, élaboré par R & D pour la défense Canada, en accentuant les facteurs économiques et les méthodes de recherche opérationnelle qui sous-tendent la structure de modélisation. D'un point de vue économique, le modèle est un hybride de multiproduits, ou d'une fonction de génération de données de sortie, et d'un modèle entrées-sorties simplifié. Un certain nombre de simulations sont réalisées, et l'on présente certains des résultats de niveau stratégique et leurs implications pour les Forces canadiennes et le processus de planification des capacités de défense.

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constrained optimization; cost model; production function; cost function; input-output tables; capabilities; capability based planning

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