MODELING SENIOR GOVERNMENT CONTRIBUTION STRATEGIES FOR FUNDING PUBLIC INFRASTRUCTURE PROJECTS

by

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Abstract

The poor state of public infrastructure in Canada has been a controversial issue for the past few years. Insufficient public transit, crumbling bridges, old water and sewage lines, and congested roads require major investments. The capital investment and the availability and quality of services provided by public infrastructure are critical in enhancing the Canadian quality of life and economic growth and productivity. Most public infrastructure in Canada is the responsibility of municipalities. Various funding sources are available for municipal governments to respond to the need for new investments in infrastructure. Transfer payments, including the grants and contribution agreements from senior levels of government, are one of the essential sources for funding public infrastructure.

This thesis explores the terms of contribution agreements through which senior levels of government fund infrastructure projects and investigates the importance of these for satisfying objectives of the project participants including those of the client, the senior level of government, delivery team or private sector, and end users. Three terms in contribution agreements are examined, including the timing of payments, the cost-sharing ratio of contribution to total eligible project cost, and the eligibility ratio as a percentage of total capital cost. The sensitivity of a subset of the participants' objectives to changes in the terms of the contribution agreement are measured in terms of total project cost incurred by the client and interest expenses during the design and construction phase from the viewpoints of the client, senior government, and contractor. A parametric deterministic cash flow model is developed to evaluate the impact of alternative senior government contribution strategies. The calculation of model performance metrics and related sensitivity analysis is carried out using MATLAB. Data gathered from the Lions Gate Secondary Waste Water Treatment Plant case study provide the opportunity for assessing cash flow model

completeness and the sensitivity of performance metrics to contribution agreement parameters, for the three procurement modes examined, namely Design-Bid-Build (DBB), Design-Build-Finance (DBF), and Design-Build-Finance-Operate-Maintain (DBFOM).

Lay Summary

Public infrastructure plays a pivotal role in enhancing Canadian quality of life, economic growth and productivity. In recent years, the government of Canada has increased its role in infrastructure funding in response to public demand for infrastructure deficit reduction nationwide. Transfer payments are one of the most important revenue sources for municipal governments to fund the infrastructure projects.

This thesis explores the terms of contribution agreements through which senior levels of government fund infrastructure projects and investigates the importance of these for satisfying objectives of the project participants. Applications of the model can inform senior governments in setting public policies for infrastructure contribution programs. The project client will also benefit from use of this model. The model results shed light on the approach the client should take in negotiating with senior levels of government, and in identifying the relative significance of and tradeoffs among the various terms of contribution agreements.

Preface

This thesis is original, unpublished, independent work by the author, Hanieh Daliri

Table of Contents

List of Tables

List of Figures

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Dedication

To my Best friend and love,

Naser

Chapter 1: Introduction

1.1 Background

Public infrastructure, including transportation networks, and environmental, educational, and recreational facilities, provides a high quality of life, productivity, and economic prosperity (Dahlby & Jackson, 2015). Every dollar spent on public infrastructure can be expected to generate more than one dollar in domestic economic activity (Loprespub, 2016). While the setting of infrastructure policies is the responsibility of federal and provincial governments, the majority of expenditure decisions are taken at the municipal level. Based on the Constitution Act of 1982, the responsibility of infrastructure is assigned to federal and provincial governments. The federal government's role in infrastructure provision is stated in Section 91 of the Act, including services for: postal; defense; navigation and shipping; ferries between two provinces; and fisheries. Public and reformatory prisons, education facilities, hospitals, local works (excluding shipping and canals), provincial courts and municipal institutions are provincial responsibilities, which are governed by Section 92. Municipalities receive their authority from the corresponding provinces through various provincial acts (Bazel & Mintz, 2014).

Moreover, Section 36(1) indicates that encouraging equal opportunities, enhancing economic development for decreasing inequality in opportunities, and providing essential public services with reasonable quality are the joint responsibility of the federal government and provinces. Section 36(2) assigns the responsibility of equalization transfers to provinces, to the federal government for provision of an equal level of basic public services at the same level of taxation (Boadway & Kitchen, 2015).

Over the past 50 years, the direct ownership of capital assets by the federal government and its role in infrastructure financing has changed dramatically. Figure 1-1 illustrates that the extent of the federal government's proportionate ownership stake in public infrastructure has decreased. For

example, in 1955 the federal government had ownership of 44 percent of public infrastructure, while the provinces and local governments owned 34 and 22 percent of capital assets, respectively. In contrast, in 2011, provincial, territorial and municipal governments owned approximately 83 percent of public infrastructure in Canada and only the remaining 17 percent was owned by the federal government (Speer & Flemming, 2016).

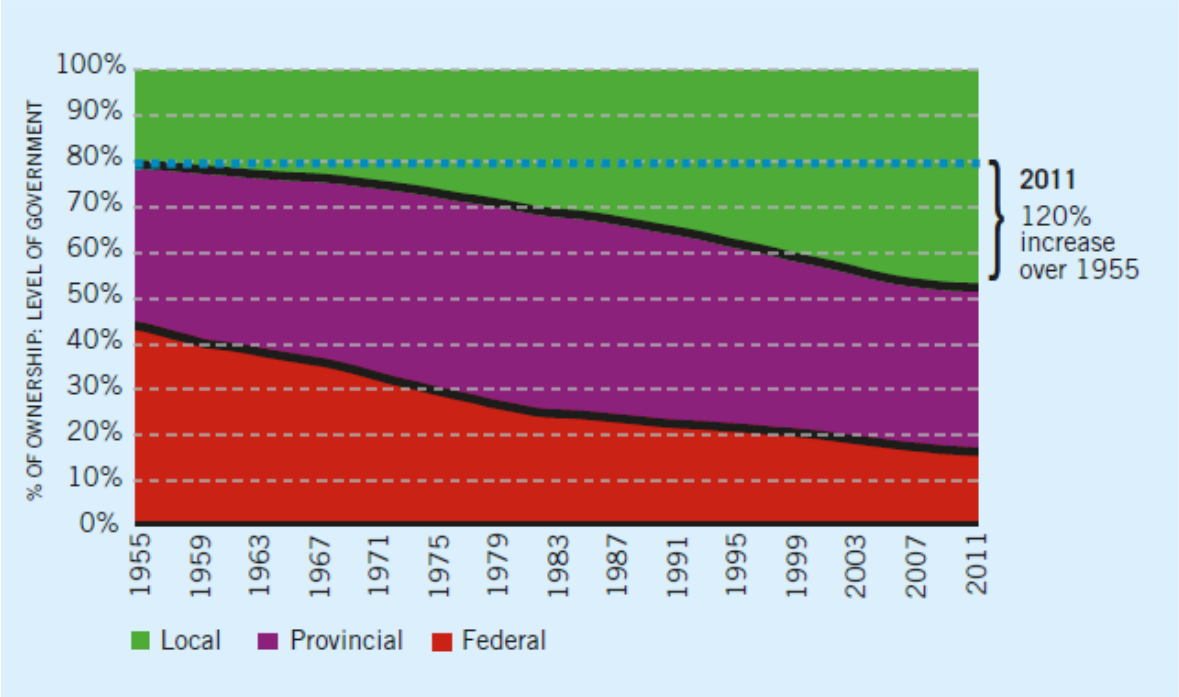

Figure 1-1 Capital-stock asset share by order of government

Source: (Speer & Flemming, 2016, Figure 1)

With the declining federal government proportionate ownership stake in public infrastructure, the federal government's role in transfer payments to provinces, territories, and municipalities to offset infrastructure spending has increased (Speer & Flemming, 2016). Historically the federal government has had a minor role in financing infrastructure that was outside its constitutional responsibility. However, after 2002, the federal government increased its role in infrastructure

financing in response to public demand for infrastructure deficit reduction in Canada (Jackson, 2015). Figure 1-2 summarizes federal spending on provincial, territorial and municipal infrastructure. The federal government introduced a series of funding programs under the 7-Year Building Canada Plan and 10-Year Building Canada Plan, including programs for projects of national significance and small communities, specific funds for projects such as border infrastructure or green infrastructure, and the Infrastructure Stimulus Fund in response to the 2009 economic recession. By implementing the aforementioned transfer programs, federal infrastructure programs have become a permanent feature of Canadian fiscal federalism (Dahlby & Jackson, 2015).

Shown in Figure 1-2, federal spending on provincial, territorial and municipal infrastructure has increased as a result of significant increases in federal funding. Annual federal support has been raised from $571 million in 2003–04 to an estimated $6 billion in 2018–19. Canada's infrastructure funding programs have contributed to over 22,000 projects in Canada that have created jobs, economic prosperity and a higher quality of life for Canadian families.

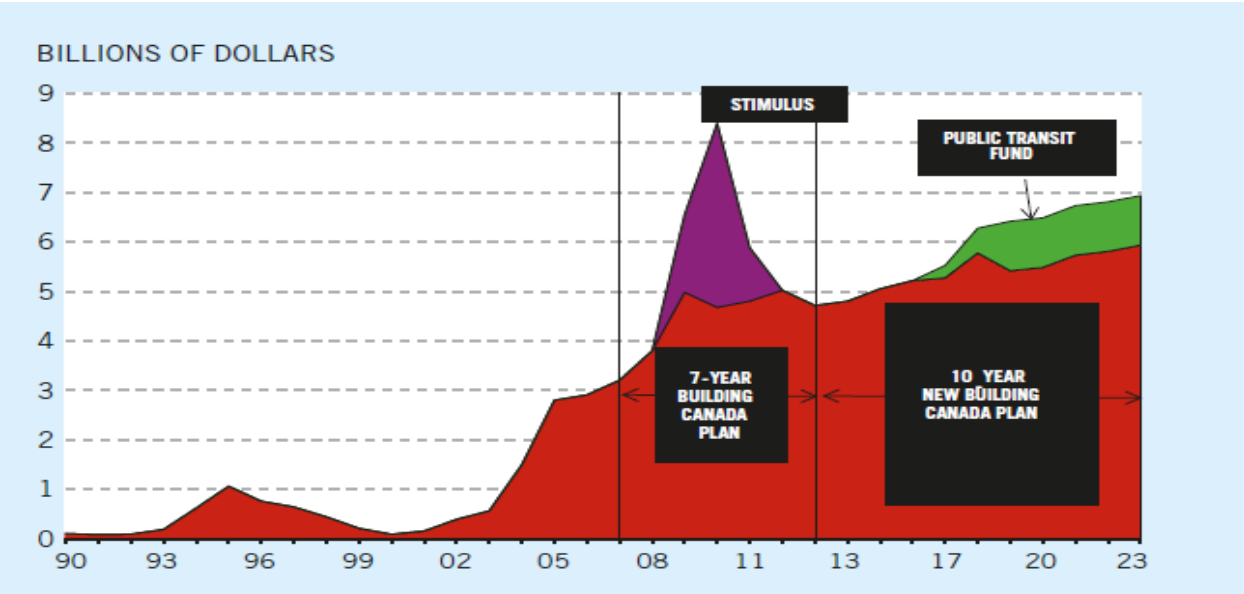

Figure 1-1 Federal spending on provincial, territorial and municipal infrastructure
Source: (Speer & Flemming, 2016, Figure 2

The federal government pursues certain goals and objectives through increasing the investment in public infrastructure. Objectives set by the Constitution Act mandate the federal government to support expenditures which provide equal opportunities, enhance economic development, decrease inequality in opportunities, and provide essential public services with reasonable quality. One of the government's key instruments in fostering its objectives and priorities are transfer payments. They contribute to building a strong society and a competitive country which is inclusive and respectful of Canadian values and furthers Canadian aims through enabling and engaging a broad variety of skills and resources outside the federal government.

The Government of Canada sets out policy for the design, delivery and management of transfer payments that comply with its objectives and priorities. The context of policies on transfer payments require the federal government to make sure that transfer payments are managed in a way that respects "sound stewardship and the highest level of integrity, transparency, and accountability ("Policy on Transfer Payments", 2015)." Furthermore, the government is committed to ensuring that transfer payment programs are designed, delivered and managed in a way which is "fair, accessible and effective for all involved. This includes departments, applicants and recipients – all of whom have important contributions to make in achieving the objectives of the government and in furthering Canadian aims ("Policy on Transfer Payments", 2015)."

To support better accountability for public monies, transfer payments should be managed in a manner that strikes the right balance between control and flexibility, and that sets the appropriate combination of good management practices, efficient administration and clear requirements for performance ("Policy on Transfer Payments", 2015).

Transfer payments are categorized as grants, contributions and other transfer payments, such as Canada Health and Canada Social Transfer Payments. Many studies have been conducted to

explore the rationale of transfer payments and assess the effectiveness of various transfer payment forms in fulfilment of federal government policy objectives. While this thesis highlights a number of these important studies, its primary focus is on evaluating the mechanism with which the federal government funds infrastructure through contribution agreements and is not on the rationale for doing so. Three variables in contribution agreements are identified - the timing of contribution payments, the cost-sharing ratio of contribution and eligibility ratio as a percentage of total infrastructure capital cost. This research explores the effect of changes in the aforementioned terms of contribution agreements on the fulfilment of project participant values, including the broad objectives of the federal government.

The results of this research provide insights that may be useful for those who formulate policies on how the federal government can make an efficient investment in public infrastructure to not only achieve its broad policy objectives, such as accountability, transparency, and stewardship, but also to consider the values of all other participants who contribute to building infrastructure.

1.2 Literature Review

Section 1.2.1 reviews research in the domain of public policy and the governmental role of municipalities, provinces and the federal government in financing public infrastructure projects in Canada. Section 1.2.2 focuses on studies in the field of modeling the capital structure of infrastructure projects financed by public funds and in analysis of such projects using decision-making frameworks.

1.2.1 Government Role in Financing Public Infrastructure Projects in Canada

Kitchen (2006) identifies and addresses concerns and issues with respect to financing major infrastructure projects in cities. He highlights innovations and practices in infrastructure financing

which are in the best interest of project stakeholders. The rationale and taxonomy of intergovernmental fiscal transfers are discussed by Adam and Maslove (2009). They discuss the innovative features of the Gas Tax Fund intergovernmental transfer, including its hybrid design, its ambitious objectives and the consideration of it as a predictable source of funds for municipalities. They also analyze its effectiveness for municipalities in providing a foundation for developing flexible long-term plans for choosing green projects and for developing a close relationship with the federal government.

In a commentary, Boyer et al (2013) discuss the need for a standard methodology for the evaluation of public and private projects. They argue that using a different discount rate, depending on whether the project is publicly funded (i.e., a lower rate) or privately funded (i.e., a higher rate) to calculate the net present value (NPV), suffers from serious flaws. Their analysis suggests that the underlying rationale behind the lower public discount rate is based on the fact that the government has the power to levy additional fees and taxes to pay off the lender if an infrastructure project incurs cost overruns. In other words, it implicitly makes taxpayers the insurer of any project failure. Bazel and Mintz (2014) argue for the imperative role of user fees and pricing mechanisms in funding infrastructure projects. They discuss how user fees can provide a dedicated revenue stream that allows municipalities to incur debt in order to address their investment needs. Finding reliable revenue sources is challenging for municipalities in funding infrastructure projects. The political costs corresponding to residential property taxes and insufficient capital transfers from provinces and federal governments to provide funds for infrastructure investment needs, necessitates optimal pricing for infrastructure, such as tolls for major roads, transit fees, and other infrastructure charges. This approach not only leads to a more efficient allocation of resources but also incentivizes the efficient use of infrastructure. Boadway and Kitchen (2014) investigate the

features of federal fiscal arrangements to ensure sufficient infrastructure spending, and reasons that governments make inadequate infrastructure investments despite its imperative role in economic prosperity. Their paper is focused mainly on the issues and principles in fiscal federalism as they relate to public infrastructure within the Canadian constitutional framework. Dahlby and Jackson (2015) provide more detailed information on the operation of federal infrastructure programs. They assess the size, scope, and design of federal infrastructure transfers based on an Infrastructure Canada database of 8012 projects funded under 13 different programs between 2002 and 2015. Tassonyi and Conger (2015) examine issues related to the capacity of municipal governments for financing adequate levels of public infrastructure. In this paper, they discuss the framework within which municipalities make decisions regarding financing the capital cost of infrastructure projects and the various sources of revenue available to them. They argue that in order for municipalities to serve Canadians to the best of their abilities, fiscal reform is vital. Jackson (2015) analyzes how federal government contribution structures under the New Building Canada Plan consist of a series of grants and contribution programs, and provide a rationale for the federal involvement, including encouraging the execution of projects with positive externalities, addressing horizontal and vertical fiscal imbalances and meeting the federal policy agenda. Siemiatycki (2016) reports on the optimal design of the Canadian Infrastructure Bank (CIB) as a key piece of the federal government's infrastructure investment plan. He provides an assessment on the merits and likely benefits of low-cost credits allocated by CIB to projects in priority sectors such as transit and affordable housing. Speer and Flemming (2016) criticize the federal government's action in shifting its focus from a long-term infrastructure contribution plan to short-term stimulation in response to economic downturns. They provide an analysis of the

necessary elements and features that every effective and strategic infrastructure plan should incorporate in order to achieve long-term efficacy and economic growth.

1.2.2 Modeling Capital Structure of Infrastructure Projects Financed with Public Funds

Zhang (2005) develops a financial evaluation methodology which applies a win-win principle by considering the interests, concerns, and requirements of the different parties involved in a project. He proposes a capital structure optimization and financial viability analysis in the face of uncertainties, including: construction; bankruptcy; and various other economic risks. This structure is subjected to the constraints imposed by different participants such as a minimum equity level, a minimum Debt Service Coverage Ratio (DSCR), and a minimum Ratio of Equity at Project Risk (REPR). The author defines the REPR as the amount of equity that is exposed to the long-term project risk, i.e., the recovery of which depends on the successful management of long-term risks and the revenue source generated over the long-term operation period, to the total amount of equity. He evaluates the impact of governmental loan guarantees and supports and discusses how a government loan guarantee would reduce the lender's risk premium that is associated with the loan. Usually, under a full governmental loan guarantee, the debt interest rate will be a risk-free rate which increases project viability. Lyer and Sagheer (2012) propose a genetic-algorithm- based model, from the viewpoint of concessionaire in Build-Operate-Transfer (BOT) projects, for finding an optimal combination of grant sought from the government, equity and debt ratio to help the private investors in bidding decisions and financing decisions. From the bid-winning perspective, the grant sought from the government is considered as the sole bid variable that determines the success of the concessionaire in winning the contract. From the viewpoint of project financing, the debt-equity ratio is the key decision variable that determines project profitability,

measured in term of the NPV of equity cash flow. A constrained multi-objective, financial optimization model, solved by genetic-algorithm, is proposed to find a set of optimal solutions for the key financial variables: equity, debt and grant ratio. Liou et al (2012) apply Monte Carlo Simulation to investigate the tradeoff relationship between the level of subsidy from the government to the project and change, if any, in the financial risk incurred by the private sector. Small-scale subsidies may be inadequate for making a non-viable project viable for the private sector, though the project may have high net economic benefit for the host society. On the other hand, large subsidies may discourage the private sector from pursuing cost efficiency. Therefore, the model developed is aimed at assessing the relationships between project viability, project risk, and the level of government subsidy. Ke Feng et al (2017) develop an equity capital optimization model using net present value analysis, to show the role of public funds, like public equity and government subsidies, in the financing of Public Private Partnership (P3) projects. They develop a genetic algorithm-based model to simultaneously optimize private equity, public equity and government subsidy for P3 projects to reach a balance between private interests and the efficient use of public funds. A Monte Carlo Simulation is applied to incorporate the effect of risk factors such as uncertainties in construction costs, operation costs, and passenger flow.

1.3 Research Questions and Objectives

The primary objective of this thesis is to explore the mechanisms which senior levels of government use to fund infrastructure projects through contribution agreements. Three variables in contribution agreements are identified including the timing of payments, the cost-sharing ratio of contribution to total eligible project cost, and eligibility ratio as a percentage of total capital cost. The effects of changes in these on performance metrics of project participants are analyzed.

Contribution payments can be provided to the project client as a single front-end loaded payment (e.g., in the first month of the project), a back-end loaded payment at the end of construction period, or broken down into multiple milestone payments or monthly payments. However, for the purpose of this thesis, only the two extremes of contribution timing are considered – i.e., only front-end loaded and back-end loaded payments.

The cost-sharing ratio of contribution payments is measured as a percentage of total capital cost which varies between contribution programs based on the ultimate recipient and type and scale of a project. Not all of the total capital cost (i.e., the all-in cost from the perspective of the client) of a project is considered eligible for a federal contribution. Eligibility constraints on cost items vary from one contribution program to another and are measured as percentage of total capital cost.

Since there are different ways of procuring a project, this research explores the effect of any change in the three variables of interest previously identified for a contribution agreement in the context of different procurement modes, and in terms of the fulfilment of project participant values including the broad policy objectives of the federal government. The value system identifies the breadth of concerns of the participants which affects their objectives and related performance metrics. The degree to which objectives are met is measured with performance metrics. The sensitivity of the fulfillment of objectives of various project participants including the client, the senior level of government, delivery team or private sector, and end users, to changes in terms of the contribution agreement, are explored.

Each participant has different objectives which are not necessarily aligned with those of other participants. Table 1-1 summarizes objectives of different project participants.

Project participant	Objectives
Client	Minimize interest expense during the design and construction phase
	Minimize the capital cost
	Provide affordable services to end users
	Provide reliable and quality services to end users
	Provide on-time and on-budget project completion
	Minimize risk
Senior government	Minimize interest expense during the design and construction phase
	Allow for capital cost contribution up to a percentage of total eligible costs and/or up to a maximum dollar value
	Minimize delivery time
	Maximize transparency and accountability
	Assure compliance with regulatory requirements
	Provide long-term infrastructure investment plan
	Foster economic growth
	Create jobs
Delivery Team Or private sector	Minimize interest capitalized during design and construction phase
	Maximize profitability of project,
	Maintain internal rate of return above the threshold
	Maintain annual debt service coverage ratio above the threshold
End-user	Minimize unit life cycle cost
	Maximize reliability and quality of services
	Maximize stability in unit operating cost over time

Table 1-1 Objectives of different project participants

Achievement of these objectives may vary under different procurement modes. In Chapter 3, performance metrics for assessing the degree of achievement these objectives under different procurement modes are discussed in detail.

This research assists in addressing a fundamental question of whether or not the different arrangements of senior government contributions affect a subset of these objectives, measured in terms of total project cost incurred by the client and interest expenses during the design and construction phase from the viewpoints of client, senior government, and contractor.

Different procurement modes may provide different opportunities for project participants in fulfillment of their values. The model presented in Chapter 3 can be extended to analyze different procurement modes. However, a comparison of procurement modes in terms of their effectiveness for achieving a certain value or objective is beyond the scope of this research.

1.4 Description of Procurement Modes

Three procurement modes, Design-Bid-Build (DBB), Design-Build-Finance (DBF), and Design-Build-Operate-Maintenance (DBFOM) are investigated. These are the predominate procurement modes currently used for infrastructure development.

The DBB procurement mode, also known as the traditional procurement mode, is the most common project delivery mode in which the client contracts separately with private design firms, during the design phase. After design development, according to the stated design specifications by the client, a competitive process is undertaken in which the contractor with the lowest bid is awarded generally a fixed price contract. During the construction period, the selected contractor undertakes the work while being monitored by the client. Following the completion of construction, the infrastructure is handed over to the client for operation and maintenance.

Under the DBF procurement mode, the client enters into a single agreement with a private contractor (a Design-Builder) to design and build the project for a fixed price by a fixed date. Under the DBF procurement mode, the project cost is financed wholly or partially by the private sector. The client identifies the level of funding that it can provide and requires the contractor to finance the project costs through short-term debt and possibly equity. Upon project completion, the client repays the contractor for the portion of design and construction costs financed by private sector along with the finance charges. Usually under the DBF procurement mode, the contractor

is repaid shortly after project completion. Following the completion of construction, the infrastructure is handed over to the client for operation and maintenance.

Under the DBFOM procurement mode, the responsibilities for designing, building, financing (wholly or partially), operating and maintaining are bundled together and transferred to a private sector partner. The private sector partners form a special purpose vehicle, called a consortium or concessionaire, to complete the project. In return for assuming these obligations, the private sector party is entitled to receive, for a specified period agreed on in the contract, called the concession period, fees from the end users of the project or payments from the client in form of performance payments or availability payments. At the end of the concession period, the infrastructure is transferred back to the client for ongoing operation.

Each of these procurement modes embodies strengths and weaknesses which impact the level of performance for a given objective. Some of the properties of the procurement modes are summarized in Table 1-3.

Procurement mode	Bid evaluation challenges	Enhanced life cycle performance	Incentivizing behavior	Innovation drivers	Time/cost Certainty	Risk transfer potential
DBB	Straightforward in evaluating compliance with specifications unless bidders propose alternative designs	While the contractor is concerned with the result of the design and construction process, it is difficult to address deficiencies in performance during operation and maintenance phase (for DBF there could be a warranty period – 1 to 2 yrs)	Contractual	Design team quality	Least	Least
DBF	More difficulty in evaluation compliance with specification. This increase progressively as more project phases are integrated in the procurement mode due to integration of financing and client value system complexity		Contractual/ Payment	Design team quality, design competition, integrated design and construction		
DBFOM		Higher potential for enhanced life cycle performance as the contractor is a direct beneficiary of design and construction team quality	Contractual/ payment	Design team quality, design competition, integrated project phases, ability to make trade-off between capital and future costs	Highest	Highest

Figure 1-2 A summary of DBB, BDF, DBFOM procurement modes properties
Source: (Russell, 2017)

In terms of senior government contributions for funding infrastructure projects, only earmarked, cost-sharing contributions in which government funds up to a maximum percentage of the total eligible project costs, while requiring the client to cover the remaining costs, are examined. The composition of the participants involved in financing the project, depends on the type of procurement mode chosen.

1.5 Research Methodology

In this thesis, a parametric deterministic cash flow model is developed to evaluate the impact of alternative senior government contribution strategies, related to the timing, magnitude and eligibility ratio of the contribution. The effects of varying these parameters are investigated and measured by evaluating the changes in the performance of project participant values and associated metrics. The calculation of model performance metrics and related sensitivity analysis is carried out using MATLAB.

Data gathered from the Lions Gate Secondary Waste Water Treatment Plant case study provide the opportunity for assessing cash flow model completeness and the sensitivity of performance metrics to contribution agreement parameters, for the procurement modes examined.

Applications of the model can inform senior governments in setting public policies for infrastructure contribution programs. The project client will also benefit from use of this model. The model results shed light on the approach these parties should take in negotiating with senior levels of government, and in identifying preferred ways to respond to or negotiate terms of contribution agreements. Moreover, the results of this study may be useful for end users who pay for public infrastructure and affect their voting decision-making to favor government investment.

Chapter 2: Financing Urban Infrastructure in Canada

The vast majority of public infrastructure in Canada is owned by municipal governments. They use various tools and approaches for financing infrastructure projects. In this chapter, sources for financing municipal infrastructure projects are discussed in detail. Moreover, an overview of the City of Vancouver's planned capital expenditures for the period 2019-2022, and their predicted revenue sources to fund capital investment, are provided to provide an example of how urban infrastructure is financed in Canada.

Intergovernmental transfers from senior levels of government have always been an important source of revenue for municipalities in funding infrastructure projects. Since 2003, as illustrated in Figure 1-2, there has been a significant rise in the federal government contribution toward funding infrastructure projects. Different types of federal contribution programs along with the economic rationale and motivation of the federal involvement in financing municipal and provincial infrastructure, is also discussed in this chapter. To provide a larger perspective, the chapter ends with an overview of federal government contribution programs in financing infrastructure projects since 2002.

2.1 Financing of Municipal Infrastructure in Canada

Municipal infrastructure includes rolling stock such as vehicles and machinery, water and sewage treatment systems, bridges, roadways, sidewalks, traffic lights and street lighting, landfill sites, furnishings, office facilities and equipment, development and purchasing of land and buildings, and all corresponding items which support the operation of the aforementioned (Tassonyi & Conger, 2015). There are two important differences between infrastructure capital and operating expenditures. First, the financing of infrastructure capital tends to be lumpy in nature, while

operation and maintenance expenditures are more regular. Second, while operating expenditures can be by subsidized via intergovernmental transfers, plus own-source revenues, infrastructure capital expenditures are mostly funded by development charges, reserves, borrowing, grants, and own-source revenues (Kitchen, 2006).

Nearly 60 percent of public infrastructure in Canada is owned and maintained by municipal governments (Tassonyi & Conger, 2015). However, only eight to nine percent of every tax dollar paid in Canada is collected by municipalities, down from 45 years ago when the local government's share from all taxes collected was 16.7 percent (Thompson, Flanagan, Gibson, Sinclair, & Thompson, 2014). Approximately less than 20 percent of total local government spending goes to capital infrastructure investment and the rest goes directly to providing services, operation, and maintenance. It is neither possible nor sustainable for municipalities to recover the infrastructure costs with only eight to nine percent of every tax dollar. Therefore, municipalities need a broad range of revenue tools to meet their infrastructure investment needs.

Of necessity, municipalities seek innovations and best practices in financing infrastructure to achieve the optimal level of municipal capital investment in order to be placed on a sound financial footing. The most imperative goal for municipalities in infrastructure financing is to finance such projects based on the benefits received. In theory, this means that residents who benefit from local infrastructure and the services it provides should pay for it. This linkage between revenues and expenditures is sometimes referred to as the Wicksellian Connection (Bird & Slack, 2014). This linkage states that decisions on the types of revenue which should be matched to fund the expenditures should be made by those who make corresponding expenditure decisions. The Wicksellian Connection results in not only a better allocation of scarce investment resources but

also a more accountable government where the taxpayers are more willing to pay taxes as they are aware of how their tax dollars are being spent (Bird & Slack, 2014).

However, the application of the benefits-based model is not always straightforward. Based on the type of infrastructure, the ability to set correct prices, taxes or fees is different. When specific beneficiaries cannot be easily identified, or the asset generates spill-over or externalities for neighboring communities, or income redistribution is a concern, or government cannot prevent those who do not pay from using services, or the measurement of output, capital and operating costs is not possible, then the application of a benefits-based model is challenging and may be even impossible (Kitchen, 2006).

2.1.1 Revenue Sources for Financing Municipal Infrastructure

As discussed earlier, urban governments in Canada take various approaches to finance public infrastructure under its jurisdiction. The following discussion describes each form of revenue source for Canadian municipalities in paying for infrastructure projects. However, few if any Canadian municipalities apply the Wicksellian Connection in its pure form.

2.1.1.1 User Fees

Local governments in Canada levy user fees to fund some or all of the costs of a range of services provided by municipalities. These include water and wastewater, storm-water management, solid waste collection and disposal, transit, and parking. User fees range from charges that are directly related to the quantity consumed, to fixed charges that are unrelated to the amount of usage, or a combination of both fixed and variable charges. Moreover, the pricing structure to cover all production and delivery costs, or only a portion of them, depends on a number of considerations.

The factors that affect the policy choices in this regard include the type of services, the local traditions, resident preferences, and the willingness of local politicians and administrators to substitute user fees for local taxes (Tassonyi & Conger, 2015) (Slack & Tassonyi, 2017).

It has been asserted that the best form of financing capital and operating costs of infrastructure is to rely on user fee systems, as they improve both urban economic decisions and budgetary plans (Bazel & Mintz, 2014). Several studies conducted by economists regarding urban infrastructure pricing show that only a few municipal governments set prices correctly in Canada. Reviewing current practices in setting user fees in Canada, one can observe deviations from what is fair, effective, and accountable (Fenn & Kitchen, 2016). For designing efficient and optimal user fees, several considerations should be taken into account, including the economics of scale, capacity constraints, and variance demand level during peak and non-peak times.

In the calculation of user charges, a decision must be made regarding which costs should be included in the calculation: capital costs, operation and maintenance costs, or both. Clearly, in the case of full-cost pricing, capital and operation and maintenance costs should be included. However, in some circumstances, e.g., when all of the capital cost is provided by a grant from a senior level of government, only operation and maintenance is appropriately included in calculation of the user charges (Amborski, 2006). This assumes no allowance is made for replacement cost.

The absence of a correct pricing system for municipal services (i.e. setting prices equal to marginal cost), results in unintended subsidies and disincentives for the efficient use of infrastructure (Tassonyi & Conger, 2015).

2.1.1.2 Property Taxes

Generally, property related taxes take a number of forms which vary across provinces. These include revenue from the general property tax on real property, special assessments, development charges, payments in lieu of taxes and a land transfer tax (Tassonyi & Conger, 2015). Urban governments usually use property taxes to finance short life expectancy-types of assets, such as police cars and fire engines, or recurrent expenditures, such as maintenance of roads, parking facilities, and street lights. For large fixed assets with long life expectancy or non-recurrent expenditures, such as museums and libraries, use of property taxes is inappropriate as current taxpayers fund a project which generates benefits for future users and this would weaken the connection between revenues, expenditures and benefits over time (Slack & Tassonyi, 2017).

2.1.1.3 Land Value Capture

Land value capture has been very popular for financing major municipal infrastructure projects in the media and by politicians in Canada, and around the world. The underlying idea behind a land value capture is to recover the windfall gain in private land values arising from two sources, public investment and a change in regulations (Slack & Tassonyi, 2017).

Public spending on infrastructure can result in an increment in the value of private lands. Such value increases can be captured in a number of ways. One way to capture the value increment on residential, commercial or industrial lands arising from the public investment is by a special assessment. A special charge or levy is added to the current property tax on private lands to capture some of the economic rents accruing to a private party who has benefited from public spending (Tassonyi & Conger, 2015). (Of course the problem is that there could be no incremental cash flow for the private party to pay the assessment until such time as they dispose of the property.)

An alternative way to capture the increase in the value of the private land arising from a public investment is Tax Increment Financing (TIF). Under a TIF, the property tax revenue collected from a designated property is divided into two parts, 1) taxes from pre-developed assessed property values, and 2) taxes on increased assessed values due to redevelopment. While the former is captured by municipalities for general use, the latter is usually dedicated to the service of debt issued to finance the public improvement.

Another approach for capturing the land value increment is by making changes in land-use regulation. The sale of building rights also known as density housing, is a method of capturing land value. For example, in Ontario, Section 37 of the Ontario Planning Act, 1990, gives permission to municipalities in Ontario to secure "facilities, services or matters (benefits) from developers, in return for heights and densities that otherwise exceed existing zoning by-law restrictions" (Moore, 2013). Likewise, based on community Amenity Contributions Agreements (CACs), the City of Vancouver exchanges density for benefits. In Toronto and Vancouver, the amount of density and the value of benefits secured are negotiated on a case-by-case basis by the municipal governments (Moore, 2013).

2.1.1.4 Development Charges and Contributions

Development charges, also known in different jurisdictions as development cost charges, capital cost charges, offsite levies, and development impact fees, are another financing tool which is used by municipalities to finance the growth-related capital costs for new development or redevelopment. The underlying principle for development charges is that development associated with growth should pay for itself and not impose a burden on existing taxpayers (Burgess, 2012). A development charge is a one-time levy on developers, and the funds collected are used to pay

for new infrastructure. Growth-related costs which are financed by development charges include "hard" costs such as water supply, sewage treatment, trunk mains, and roads. However, in some jurisdictions "soft" costs for services like museums, libraries, recreation centers, and schools are also considered as growth-related costs.

2.1.1.5 Intergovernmental Transfers

Another source for municipalities to fund their infrastructure investment needs is asking for funds from higher levels of government, especially when the public refuses to pay more fees or taxes to support infrastructure funding (Bazel & Mintz, 2014).Traditionally, intergovernmental transfers have been a main part of the decentralized Canadian fiscal framework. Since confederation in 1867, the features of intergovernmental transfers with respect to magnitude, nature, and number have changed. However, their mission of "achievement of advantages of decentralization while minimizing its adverse consequences for national objectives" (Boadway, 2007) has remained the same throughout time.

Since 2005, the gas tax fund transfer has been the largest federal contribution in financing major and strategic infrastructure of municipalities. Provinces also contribute to paying for municipal infrastructure (Slack & Tassonyi, 2017). The underlying rationale for grants from senior levels of government, federal and provincial, to pay for capital infrastructure is based on economic justifications that include encouraging projects that generate spill-overs, addressing vertical and horizontal imbalances in local government, and meeting a certain senior government policy agenda (Jackson, 2015). A detailed description of the types, rational and features of intergovernmental transfers is provided in the next section.

2.1.1.6 Borrowing

While short-term borrowings can be used by municipalities to finance capital expenditures or an unexpected deficit in the operating budget, long-term borrowing is restricted to financing capital expenditures. Infrastructure projects which benefit future residents, and encourage fairness, efficiency, and accountability, such as fire and police infrastructure, recreational facilities, libraries, transportation infrastructure, solid waste facilities, and water and sewer systems, are almost always financed by borrowing. In theory, the interest charges and principal of debt financing should be paid either by local tax revenues, if the infrastructure benefits the municipality in general and not a specific beneficiary, or user fees if the infrastructure generates benefits for specific residents (Kitchen & Tassonyi, 2012). Figure 2-1 shows the extent of municipal borrowing in Canada from 2007 to 2017. There is a steady increase in net financial liabilities (financial liabilities minus financial assets, i.e., liquid or non-physical assets that derive their value from a contractual claim, such as currency and deposits, equity and investment funds, insurance and pensions, debt securities, and other receivable accounts; financial assets are opposite to tangible physical assets which has a physical form such as land, property, or other tangible physical assets) since 2007, followed by a decline after 2012 and then fluctuation until 2017.

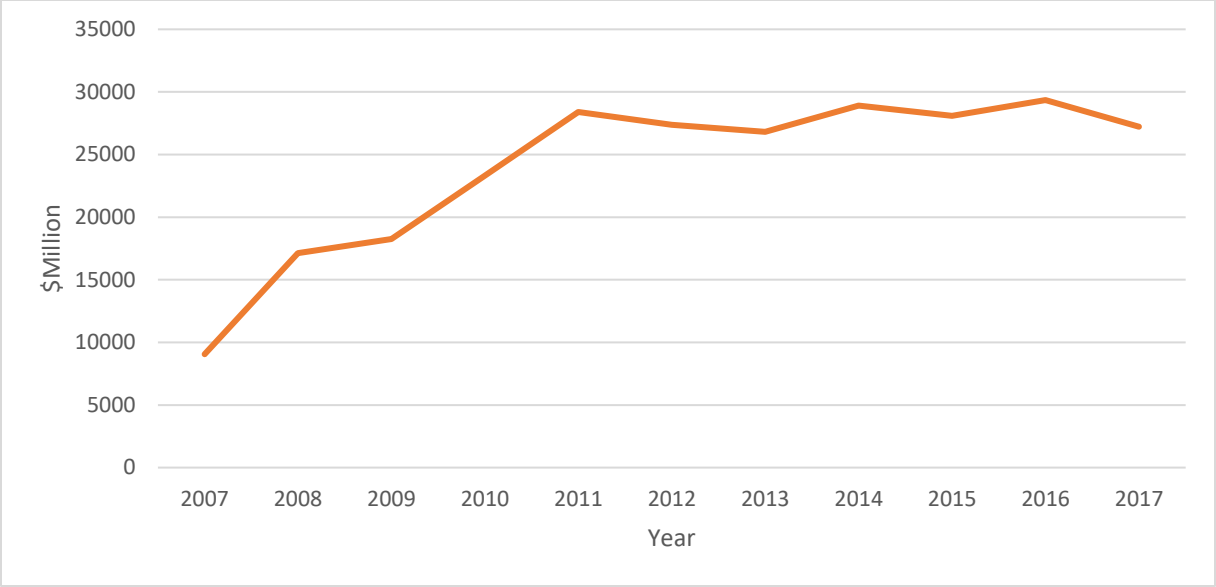

Figure 2-1 Net financial liabilities, all municipalities, Canada, 2007-2017

Source: Statistics Canada, Table 10-10-0020-01

The amount of money that Canadian municipalities can borrow is restricted by provincial/territorial regulations including restrictions derived from a formula-based approach that apply to the approval process. Table 2-1 summarizes these formula-based restrictions for Canadian provinces and territories as well as approval process-based restrictions.

MUNICIPAL DEBT LIMITS AND RESTRICTIONS BY PROVINCE	
Province	**Restrictions Based on a Formula**
Nova Scotia	Debt-service ratio limit of 30 percent of own-source revenues
New Brunswick	Annual borrowing less than two percent of the assessed value of the real property of the municipality.
Ontario (Excluding Toronto)	Debt-service limit of 25 percent of own-source revenue adjusted by debt service payments to other governments; the City of Toronto sets its own policy.
Manitoba	Total debt, maximum of seven percent of municipal assessment, annual debt service not to exceed 20 percent of annual revenue. The guideline is set by the Manitoba Municipal Board.
Alberta	The Cities of Edmonton, Calgary, Medicine Hat and the regional municipality of Wood Buffalo: Debt limit of 2.0 times total revenue excluding capital transfers; debt-service limit of 35 percent of revenue; debt limit of 1.5 times of total revenue excluding capital transfers; debt-service limit of 25 percent of revenue
British Columbia	The City of Vancouver: aggregate debt not to exceed 20 percent of assessed value based on the average assessment of the previous two years; own policy limit of 10 percent of operating expenditures. Debt-service limit of 25 percent of consolidated re-occurring own-source revenues. Municipalities whose economies are not well-diversified may face a lower limit administered by the Municipal Finance Authority of BC.
Yukon	Three percent of the current assessed value of all property.
Northwest Territories	Debt service not to exceed 25 percent of own-purpose revenues.
Restrictions Based on an Approval Process	
Newfoundland & Labrador	Ministerial approval.
Nova Scotia	Ministerial approval for lease agreements or commitments in excess of $100,000; $500,000 for Halifax Regional Municipality
Quebec	Ministerial approval
Saskatchewan	Established by the Saskatchewan Municipal Board upon application
Nunavut	Ministerial regulation (federal)

Table 2-1 Municipal debt limits and restrictions by province
Source: (Slack & Tassonyi, 2017)

Currently, although municipalities have the capacity for more borrowing, they refuse to do so. The high cost of borrowing, especially the poor experience with high-interest costs in the 1980's is the major reason for the unrealized borrowing capacity in municipalities (Kitchen, 2006).

2.1.1.7 Reserves

Reserves, that is, funds set aside for capital expenditures, are basically the reverse of financing through borrowings. Instead of borrowing to finance capital expenditures and paying off this debt in the future, reserves reverse that timetable. Usually, a small percentages of local property tax known as a "Capital Levy" is set aside in an interest-earning account which is separated from general revenues. These reserves are eventually withdrawn to finance either general capital projects or specific projects. However, the use of reserves breaks the link between revenue and expenditures as the current taxpayers pay for the capital infrastructure of future generations (Kitchen, 2006).

2.1.2 Brief Overview of the City of Vancouver Capital Plan for 2019-2022

In order to provide an example of financing urban infrastructure in Canada, i.e., capital expenditures and revenue sources to cover these expenditures, an overview of the City of Vancouver capital plan for 2019-2022 is presented. This overview provides insights on the breadth of municipal infrastructure as well as the magnitude of the expenditure involved with a sizeable city.

Currently, the City of Vancouver owns $25 billion of infrastructure and amenities excluding land but including underground water and sewer infrastructure, roadways, walkways and bikeways, affordable housing, community facilities, parks and open spaces, public safety facilities, and

service yards. Due to the continued growth of the City and to enhance its sustainability and resilience, it is imperative to make long-term and strategic infrastructure investment decisions. Table 2-2 summarizes the planned capital expenditure for investment in both existing and new infrastructure and amenities.

Capital Expenditure	$ Million
Affordable Housing	$ 540
Childcare	$ 123
Parks and open spaces	$ 264
Art & Culture	$ 185
Community Facilities	$ 234
Public Safety	$ 48
Civil Facilities and Equipment	$ 108
Transportation & Street Use	$ 311
Water	$ 616
Solid Waste	$ 92
Renewable Energy	$ 41
Technology	$ 100
Emerging Priorities	$ 88
Overhead	$ 20
TOTAL	**$ 2,770**

Table 2-2 Planned capital expenditure by sector, City of Vancouver, 2019-2022
Source: ("City of Vancouver", 2018)

The proposed investment of $2.77 billion includes investment in the renewal of existing infrastructure and amenities as well as new infrastructure and amenities. Figures 2-2 and 2-3 show the total investment in each sector in detail.

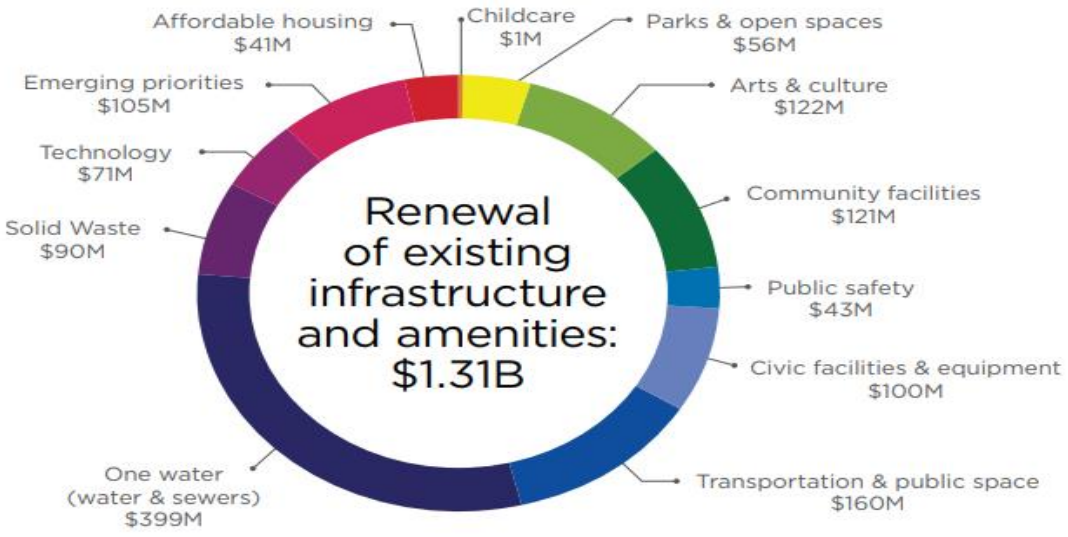

Figure 2-2 Planned capital expenditure for renewal of existing infrastructure and amenities, City of Vancouver, 2019-2022

Source: ("City of Vancouver", 2018)

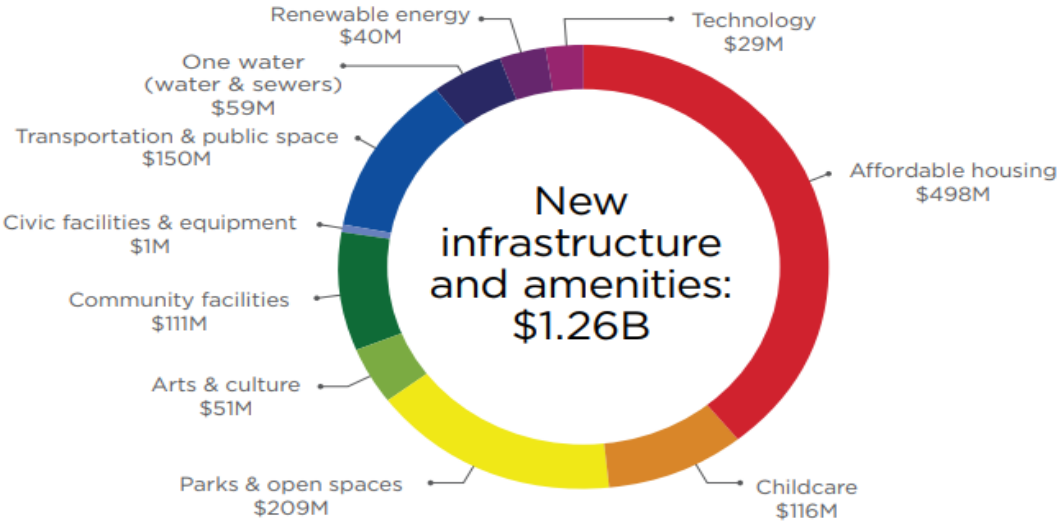

Figure 2-3 Planned capital expenditure for new infrastructure and amenities, City of Vancouver,2019-2022

Source: ("City of Vancouver", 2018)

Table 2-3 provides a brief summary of the City of Vancouver planned funding sources to cover the cost of capital expenditures over the period of 2019-2022. Figures 2-4 and 2-5 show the

allocation of funding sources for covering the capital expenditure of both existing and new infrastructure and amenities.

Funding Sources		$ Million
City Contribution	**$**	**1,049**
Debt financing	$	495
Property tax	$	206
Utility Fees	$	202
Tax & fee funded capital reserves	$	146
Development contributions	**$**	**1,615**
Development connection fees	$	110
In-kind development contributions	$	569
DCLs and cash CACs reserves	$	936
Partner contributions [1]	**$**	**107**
TOTAL	**$**	**2,771**

Table 2-3 Planned funding sources for capital expenditures, City of Vancouver, 2019-2022
Source: ("City of Vancouver", 2018)

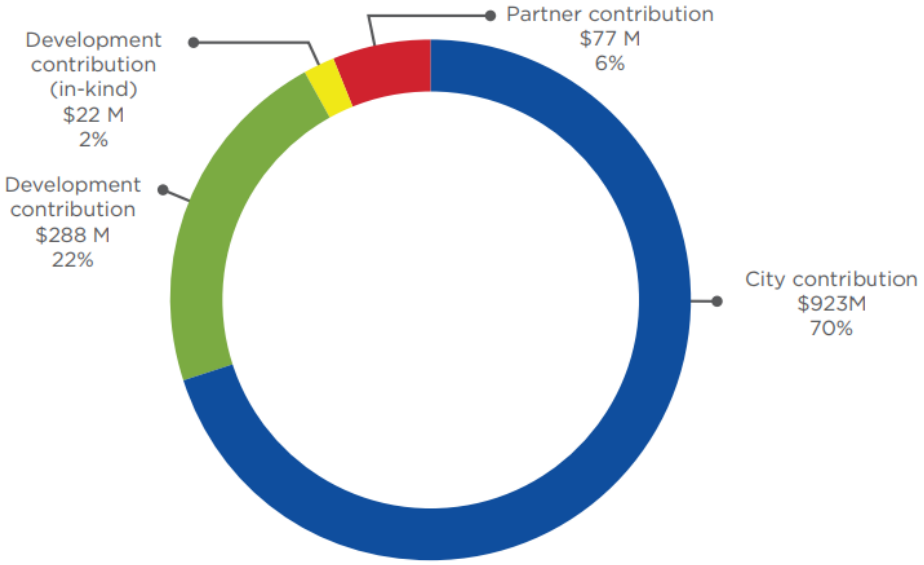

Figure 2-4 Funding sources for existing infrastructure and amenities, City of Vancouver, 2019-2022 – total expenditure of $1.31 billion
Source: ("City of Vancouver", 2018)

[1] Partner contribution includes contribution from other levels of governments (federal, provincial and regional), nonprofit agencies, foundations and philanthropists.

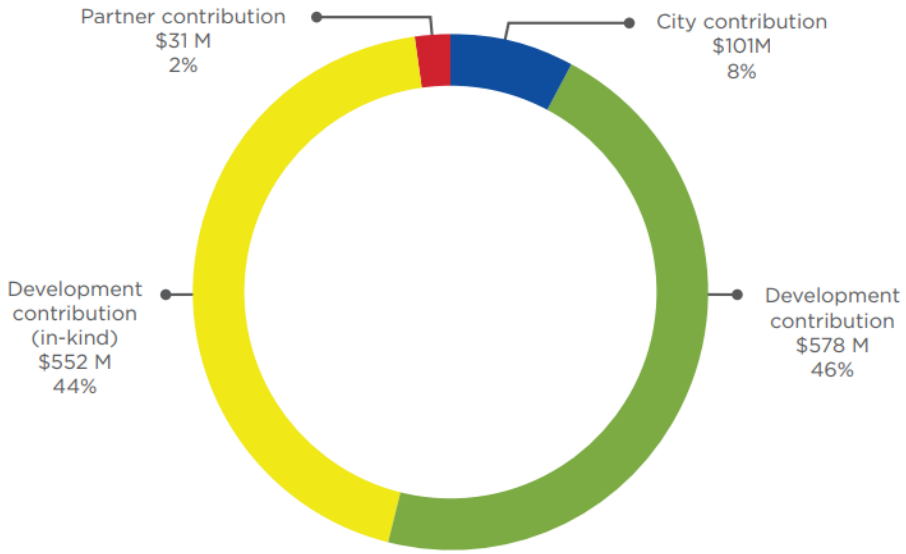

Figure 2-5 Planned funding sources for new infrastructure and amenities, City of Vancouver, 2019-2022
Source: ("City of Vancouver", 2018) total expenditure of $1.26 billion

As the focus of this thesis is on senior level of government strategies in contributing funds to public infrastructure financing, the next section discusses the different types of intergovernmental transfers. Also discussed is the economic rationale for this source of revenue, available to municipalities, to fund public infrastructure.

2.2 Intergovernmental Fiscal Transfers in Canada

Based on the Public Sector Accounting Board, intergovernmental fiscal transfers are a transfer of monetary assets to another level of government. The government making the transfer does not: "(a) receive any goods or services directly in return, as would occur in a purchase/sale or other exchange transaction; (b) expect to be repaid in the future, as would be expected in a loan; or (c) expect a direct financial return, as would be expected in an investment (Boadway, 2007)." Throughout history, intergovernmental transfers have played a central role in the highly decentralized Canadian fiscal framework. As discussed in Chapter 1, historically, the federal government has had a minor role in financing infrastructure that was outside its constitutional

responsibility. However, after 2002, the federal government increased its role in infrastructure financing in response to public demands for infrastructure deficit reduction in Canada (Jackson, 2015). The federal government introduced a series of funding programs, namely a 7-year Building Canada Plan and 10-year Building Canada Plan, inclusive of funding programs for projects of national significance, small communities, projects such as border infrastructure and green infrastructure, and the Infrastructure Stimulus Fund, in response to the 2009 economic recession. By implementing the aforementioned transfer programs, the federal infrastructure programs have become a permanent feature of Canadian fiscal federalism (Dahlby & Jackson, 2015).

As a result of a significant increase in federal funding, annual federal support has been raised from $571 million in 2003–04 to an estimate of $6 billion in 2018–19. Canada's infrastructure funding programs have contributed to over 22,000 projects in Canada that have created jobs, economic prosperity and a higher quality of life for Canadian families.

2.2.1 Economic Rationale for the use of Intergovernmental Transfers

Given the increased role of the federal government in the provision of infrastructure, this section discusses the economic rationale and motivation of federal involvement in the financing of municipal and provincial infrastructure.

2.2.1.1 Vertical Fiscal Imbalances

Vertical imbalance occurs when there is an inconsistency between revenue means and constitutionally-assigned expenditures at a different level of government in a federation (Shah, 1994). The reason for this vertical gap has roots in inappropriate expenditures and tax assignments,

restricted or unproductive tax base available for junior levels of government, limited flexibility in raising own-source revenue, and regional tax competition (Shah, 1994).

According to Dahlby (2005), the difference between the marginal cost of raising public funds through a senior level of government can provide an acceptable measure of the degree of vertical fiscal imbalance. The marginal cost of raising public funds for higher levels of government is less than for lower levels of government. In other words, raising one additional dollar in taxes imposed by the federal government has a less negative impact on individuals and firms, than one additional dollar in tax revenue collected by provinces or municipalities (Jackson, 2015)

Table 2-4 shows the most recent estimate of the marginal cost of public funds for provincial personal tax income for the year 2013 calculated by Dahlby and Ferede (2012 & 2015).

Province	Marginal Cost of Public Funds
Newfoundland and Labrador	2.66
Prince Edward Island	2.80
Nova Scotia	2.45
New Brunswick	1.73
Quebec	2.68
Ontario	3.60
Manitoba	2.42
Saskatchewan	2.38
Alberta	1.41
British Columbia	2.86
Federal Government	1.17

Table 2-4 The marginal cost of an additional dollar of public funds from personal income taxation by Canadian provinces in 2013 (by Nova Scotia in 2006) and the federal government in 2006
Sources: Provincial MCF: (Dahlby & Ferede, 2015), federal and Nova Scotia MCF: (Dahlby & Ferede, 2012)

Table 2-4 shows that there is a significant difference in the marginal cost of raising one extra tax-dollar at the federal level vs the provincial level, especially for some provinces like Ontario with a 3.60 marginal cost, while the federal marginal cost of increasing one additional tax-dollar is 1.17. In other words, financing expenditure at the provincial level is more costly than at the federal level. Therefore, the limited ability of a lower level of government to raise funds, along with the federal government's relative efficiency in raising additional funds, provide the motivation for the federal government to address the vertical fiscal imbalances by transferring money to provinces and municipalities.

2.2.1.2 Horizontal Fiscal Imbalances

Horizontal imbalance happens when there is a disparity between revenue raising potential and fiscal needs of governments at the same level in a federation (Shah, 1994). The inconsistency in fiscal capacity in governments at the same level will lead to the inability of governments to offer the same level of service to their residences at the same level of taxation.

The difference in fiscal capacity across the same level of government in a country like Canada can arise because, for example, a tax base might be available to one province or municipality while it is not to others, and there are different income levels in provinces, or disparity in expenditure needs, based on populations and location (Ma, 1997).

Referring to Table 2-4, estimates made by Dahlby and Ferede (2012 & 2015) tell the same story. The marginal cost of increasing tax revenue ranging from 1.41 in Alberta to 3.60 in Ontario shows the horizontal fiscal imbalances in Canada. As mentioned earlier, the responsibility of encouraging equal opportunities, enhancing economic development to decrease inequality in opportunities, and providing essential public services with reasonable quality to all Canadians, lies with both the

federal government and the provinces. To address the horizontal fiscal imbalances and to provide the same level of public services for all Canadians, the federal government makes equalization transfers to provinces with the below-average revenue-raising capacity to bring them closer to average.

2.2.1.3 Interjurisdictional Spill-overs

Positive externalities or spill-overs generated from a project in one jurisdiction might benefit people in other jurisdictions whom did not contribute to costs. Generally, local governments do not consider the benefit of externalities to other jurisdictions in their investment decision-making as they only have a responsibility to serve their own residents. This will result in investment in public services at a lower than optimal level. Co-ordination between different local governments to invest in such a project is challenging. It is difficult, if not impossible, to measure how much each local government benefits from such an investment and thus how much they should contribute. To encourage investment in a project with externalities, the higher level of government provides such projects with cost-sharing contributions. By making these projects cheaper for local governments, it encourages them to take the investment with spill-over into account, which they would not do otherwise (Jackson, 2015).

While projects with horizontal externalities directly benefit people in other jurisdictions, as explained above, vertical externalities exist when an increase in a jurisdiction's income will result in an increase in tax revenues for the federal government. This can provide a benefit to all Canadians as it eventually leads to an increase in federal government expenditure or a reduction in tax rates.

Types of projects with horizontal externalities are quality-of-life infrastructure, such as wastewater treatment plants on interprovincial watersheds, or productivity-enhancing projects such as national highways or ports that transfer goods and products to other jurisdictions. In the case of the latter type of infrastructure, the benefit of increasing after-tax incomes of individuals and firms will lead to an increase in federal tax revenues and provide both vertical and horizontal externalities (Dahlby & Jackson, 2015).

2.2.1.4 Pursuing Federal Government Policy Goals

Intergovernmental fiscal transfers might be used to pursue a federal government's policy goals. An example of an enhanced federal policy goal is the upgrading of primary wastewater treatment plants to secondary treatment plants by the end of 2020. As a result of requirements set by the federal wastewater effluent regulation, the federal government made a contribution of $212.3 million to Metro Vancouver for upgrading the Lions Gate Secondary wastewater treatment plant to help them fulfill this requirement. (An additional contribution of $193million was made by the provincial government.) Another example of intergovernmental transfers to advance federal policy goals is the political decision of making direct transfers to jurisdictions with high political power to achieve support from their voters (Sato, 2007).

2.2.2 Taxonomy of Intergovernmental Transfers

Intergovernmental transfers are broadly categorized in two groups: unconditional or general-purpose transfers, and conditional or earmarked transfers (see Figure 2-6). Unconditional transfers provide for general budget support, with no condition on the specific types of projects or costs attached. These transfers are intended to improve inter-jurisdictional equity without neglecting local autonomy. On the other hand, conditional transfers restrict the recipient to spend the money

based on specific conditions, e.g., they are required to spend money on specified eligible costs or projects. Conditional transfers may involve a matching provision, which requires the recipient to finance a pre-specified percentage of cost using their own resources. Therefore, they are classified in two categories: matching and non-matching transfers. In non-matching transfers, the senior government offers a given amount of funds without the recipient having to match them, while, in matching transfers, the recipient is required to cover a certain percentage of the costs. Matching transfers are either open-ended or closed ended. Under open-ended transfers, there is no limit on the amount of funds provided by the donor, as long as the recipient covers its share. However, under closed-ended programs (the preference of senior levels of government), the donor only contributes up to a certain dollar value. In the following section detailed descriptions of the aforementioned transfer payments are provided.

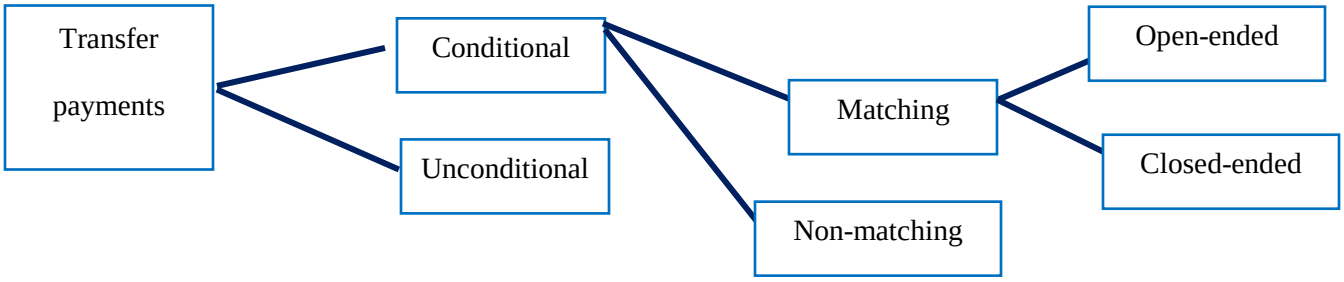

Figure 2-6 Taxonomy of intergovernmental transfers

2.2.2.1 Unconditional Transfers

Unconditional transfers do not restrict the recipient in how to use the money, which provides the recipient with flexibility in spending. General purpose transfers are deemed as budget support which allows the recipient to follow their own objectives and enhance the local welfare (Shah, 2006).

Suppose there is a public good A, e.g., transportation services and it has a price, say P_A. Since Unconditional transfers only augment the recipient resources, they only have an income effect[2] by shifting the recipient's budget line, B-B', upward and to the right to C-C' in which B-C (=B'-C') is equal to the transfer payment (see Figure 2-7). The unconditional transfer payments increase the recipient's income, which goes to acquiring more public good A as well as other public goods such as tax relief to residents. Since unconditional transfers can be spent on any combination of public good A or any other public goods they do not affect the relative price of good A, P_A, nor the relative price of other goods, hence there is no substitution effect[3]. In other words, the relative price of good A remains the same and it increases the spending on good A only as much as it increases the spending on other public goods and services. Therefore, it can be inferred that they have the least stimulative effect on good A.

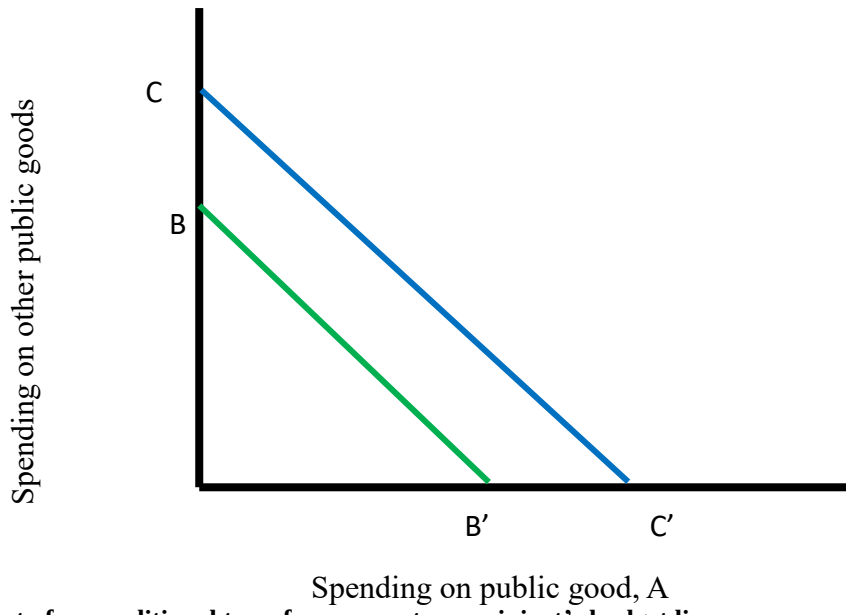

Figure 2-7 Effect of unconditional transfer payment on recipient's budget line
Source: (Shah, 2006)

[2] Income effect that expresses the change in the demand for a good due to a change in consumer's income is called income effect.
[3] Substitution effect describes how the demand for a good is impacted by changing in the price of the good relative to another good.

2.2.2.2 Conditional Transfers

Conditional transfers play a pivotal role in achieving the senior government's objectives and priorities as they are designed to motivate the recipient to spend on a specific area such as infrastructure and health care facilities ("Policy on Transfer Payments", 2008).

Conditional transfers can reflect either input-based conditionality or output-based conditionality. While the former specifies the type of cost that can be financed, such as capital expenditures, operating and maintenance costs, or both, the latter requires fulfillment of certain outcomes by the recipient regarding service delivery. Shah (2006) explains that input-based conditional transfers can be "intrusive and unproductive" while output-based conditional transfers can "advance grantors' objectives while preserving local autonomy." As seen in Figure 2-6, conditional transfers are divided into two groups, non-matching and matching transfers.

2.2.2.2.1 Non-matching Transfers

As illustrated in Figure 2-8, like unconditional transfers, a non-matching transfer also shifts the recipient's budget line B-B' to B-C-C', where at least O-N (=B-C) of assisted public good is acquired. Herein, because of the conditionality, the budget line is curtailed above the amount of transfer (=B-C). It means that spending on public goods above line B-C cannot be funded with the transfer which guarantees that at least O-N of the specific public good, A, is acquired. Conditional non-matching transfers are most appropriate for subsidizing public goods or services which have higher priority for senior levels of government than local governments.

Unconditional transfers allow recipients to pursue their own objectives and priorities. With a given level of assistance provided by senior government, the resources of the recipients are augmented, while their spending patterns remains the same, as the recipient is not required to match the senior

government spending from their own resources. However, to ensure that funds are spent on expenditures which are related to the grantors' priority, the grantor may sacrifice some recipient satisfaction. Grantors like the federal government do not want the lower level of government to spend their funding on areas other than the federal priority. Under this circumstance, the conditional non-matching transfers are best suited to guarantee the expenditure of funds on targeted expenditure areas while preserving local priorities among different activities and ensuring efficient allocation to foster the senior government's interest area.

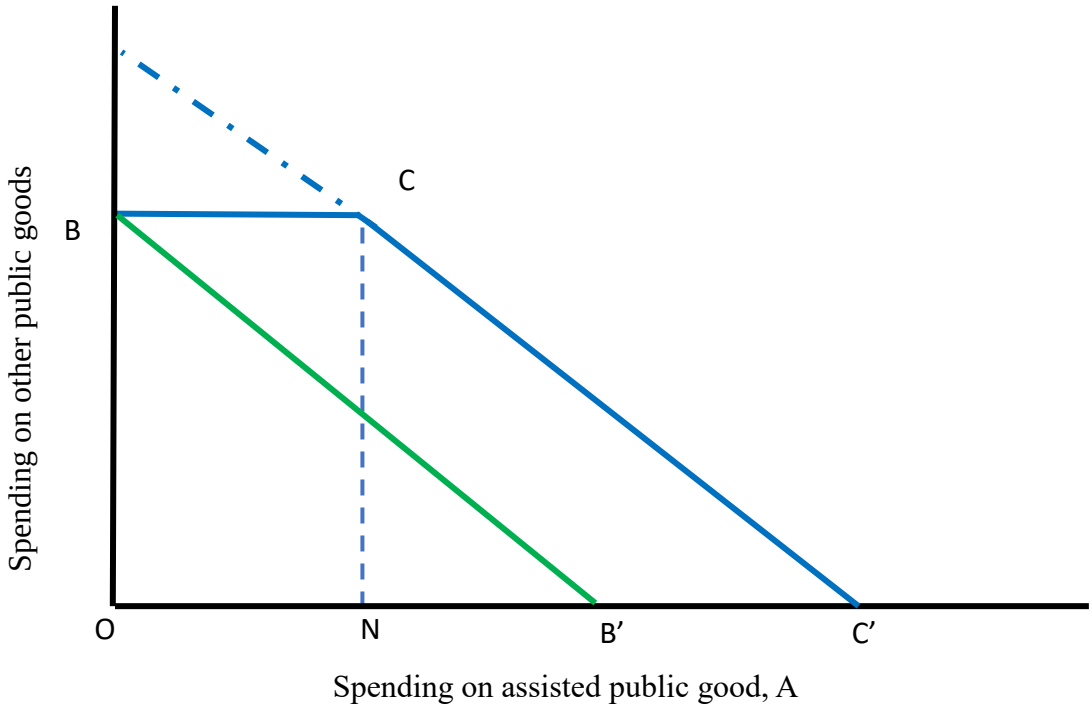

Figure 2-8 Effect of non-matching transfer payment on recipient's budget line
Source: (Shah, 2006)

2.2.2.2.2 Matching Transfers

Under matching transfers, also known as cost-sharing programs, the recipient is required to use its own resources to cover a certain percentage of expenditures. The matching transfers shift the local government budget line upward and to the right (see Figures 2-9 and 2-10), allowing the local

government to acquire more of a specific public good, A. The conditional matching transfers have both income effects and substitution effects. They provide the local government with more available resources which results in more spending on both assisted good A and other groups of goods and services (income effect). By requiring the recipient to spend the transfer payments on good A, the relative price of good A, P_A, compared to other goods and services decreases, which results in acquisition of more assisted good, A by the recipient by a given budget (substitution effect). Both effects results in more spending on good A by the recipient.

Matching grants are classified into categories: closed-ended and open-ended. Under closed-ended matching transfers, the senior government only contributes up to a maximum dollar value. Figure 2-9 shows the effect of closed-ended matching transfers on the recipient budget line, B-B'. Suppose that federal government contributes to the acquisition of a public good A at a matching rate of 33%, i.e., 33% of P_A . This means that there is one-dollar assistance from the senior government for every two dollar of recipient spending on good A up to a pre-specified limit. Therefore, the budget line becomes B-C-C'. Initially, costs are shared on a one-third: two-thirds basis up a level of ON, at which the subsidy level CE is reached. Beyond O-N, the expenditure on good A do not receive any subsidy and the slope of budget line returns back to 1:1 rather than 1:2.

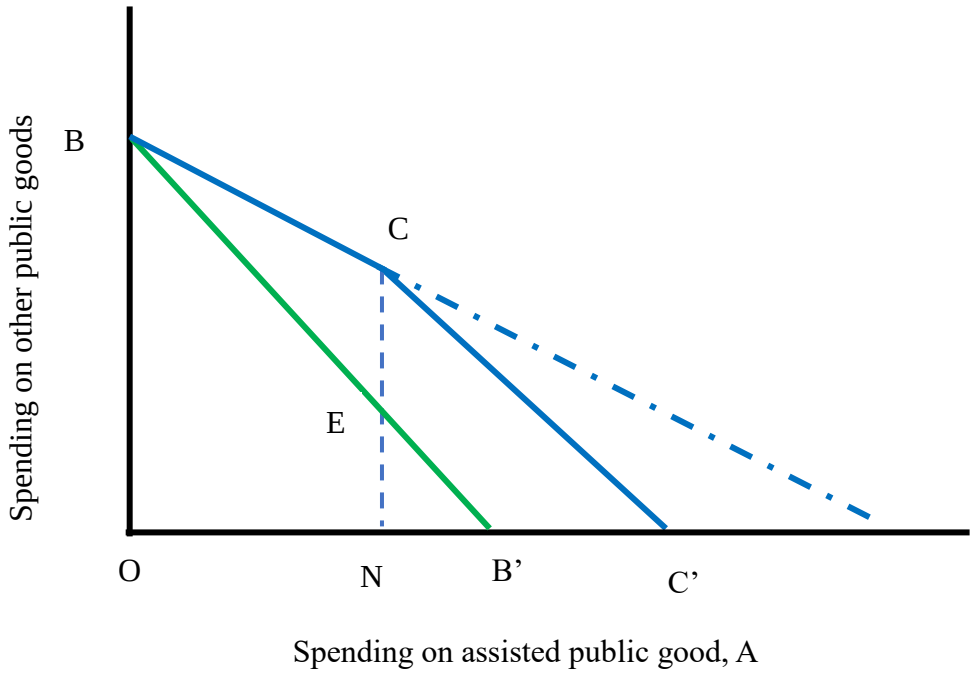

Figure 2-9 Effect of close-ended matching transfer payment on recipient's budget line
Source: (Shah, 2006)

Open-ended matching grants require that funds be spent for specific purposes and that the recipient match the funds to a specified degree while there is no limit on available assistance through matching provisions. Figure 2-10 illustrates the effect of open-ended matching transfer payments on a local government budget line. The subsidy of 33% on a specific public good, A, from the senior government moves the budget line from B-B' to B-C'. This means that, for any level of other goods and services, the local government can obtain one-third more of the public good, A. Moreover, as long as two-thirds of expenditure on public good A is covered by local government, there is no limit on the federal assistance for provision of good A.

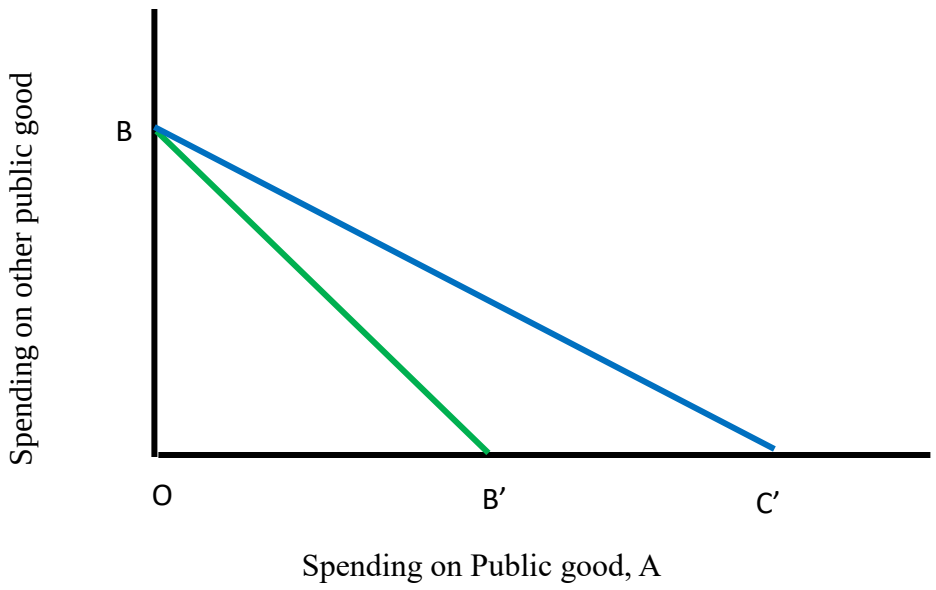

Figure 2-10 Effect of open-ended matching transfer payment on recipient's budget line
Source: (Shah, 2006)

2.3 Federal Government Contribution Programs since 2002

The availability of federal government funding for infrastructure financing is continually increasing. Through the Investing in Canada Plan, the federal government is investing more than $180 billion over 12 years directed toward advancing five main infrastructure priorities including: public transit, green infrastructure, social infrastructure, trade and transportation, and public and northern communities' infrastructure. These investments are being delivered by 14 federal departments and agencies. The Investing in Canada Plan includes a $14.4 billion federal investment in rehabilitation, repair, and modernization of existing public transit, and green and social infrastructure which was announced under the 2016 budget. $81.2 billion of funding became available across the aforementioned five priority infrastructure areas under the 2017 budget, and $92.2 billion of funding became available through existing programs such as the 2014 New Building Canada Fund and Gas Tax Fund ("Infrastructure Canada", 2018).

Infrastructure Canada is responsible for delivering the majority of funding programs. Over $56 billion of $95 billion of funding programs was announced, under the 2016 and 2017 budgets respectively, and many ongoing funding programs, such as the New Building Canada Plan and Gas Tax Fund, are delivered through Infrastructure Canada.

Infrastructure Canada is in close collaboration with all levels of government and other partners to provide long-term and strategic infrastructure planning. Infrastructure Canada enables investment, through transfer payments, grants and contributions, in support of social, green, transit, trade and transportation infrastructure to achieve government's goal of "building an economically vibrant, strategically planned and sustainable country" ("Investing in Canada Plan", 2018).

2.3.1 Infrastructure Canada Funding Programs

Table 2-5 lists the federal government funding programs administrated by Infrastructure Canada. As the focus of the thesis is on federal contribution programs to infrastructure projects, Figure 2-6 compares the amount of money delivered to projects under Infrastructure Canada contribution programs since 2002.

Investing in Canada Plan Programs	**Ongoing Programs Included in Investing in Canada Plan**	**Fully Allocated or Closed Funding Programs**
Investing in Canada Plan Bilateral Agreements (Budget 2017)	Gas Tax Fund (GTF)	Border Infrastructure Fund (BIF)
Clean Water and Wastewater Fund (CWWF)	New Building Canada Fund – Provincial-Territorial Infrastructure Component – National and Regional Projects (PTIC-NRP)	Building Canada Fund – Communities Component (CC)
Disaster Mitigation and Adaption Fund (DMAF)	New Building Canada Fund – Provincial-Territorial Infrastructure Component – Small Communities Fund (PTIC-SCF)	Building Canada Fund – Communities Component Top-Up (CC Top Up)
Municipal Asset Management Program (MAMP)		Building Canada Fund – Large Urban Centers Component (LUCC)
Municipalities for Climate Innovation Program (MCIP)		Building Canada Fund – Major Infrastructure Component (MIC)

Public Transit Infrastructure Fund (PTIF)		Building Canada Fund – National Infrastructure Knowledge Component (NIKC)
Smart Cities Challenge (SCC)		Canada Strategic Infrastructure Fund (CSIF)
		G8 Legacy Fund (G8LF)
		Green Infrastructure Fund (GIF)
		Infrastructure Stimulus Fund (ISF)
		Inuvik to Tuktoyaktuk Highway Program (ITH)
		Municipal-Rural Infrastructure Fund (MRIF)
		New Building Canada Fund – National Infrastructure Component (NIC)
		National Recreational Trails Program (NRT)
		P3 Canada Fund
		Provincial-Territorial Infrastructure Base Fund (PTBase)
		Public Transit Fund (PTF)
		Research, Knowledge, and Outreach Program (RKO)

Table 2-5 Federal government funding programs administrated by Infrastructure Canada
Source: ("Infrastructure Canada", 2018)

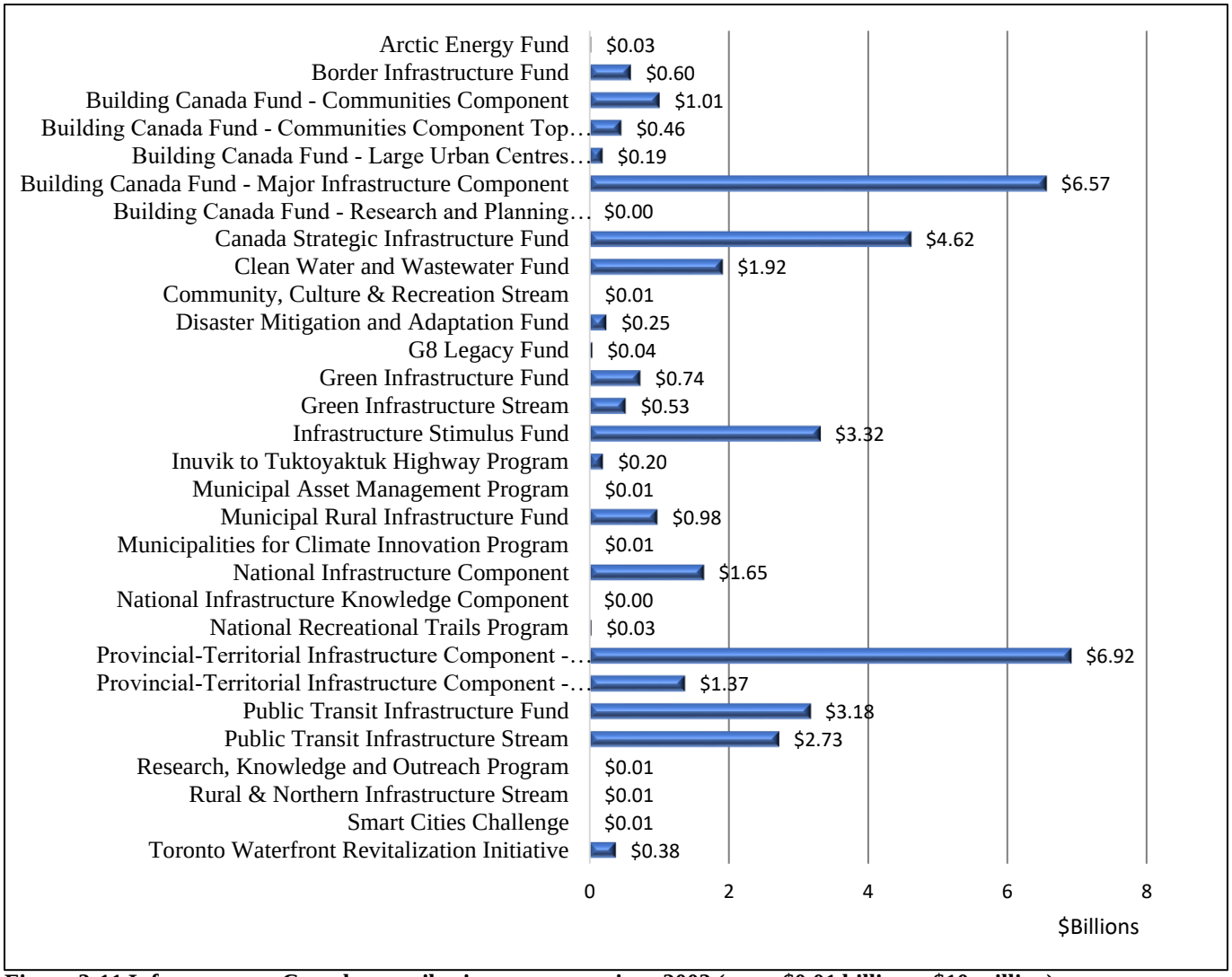

Figure 2-11 Infrastructure Canada contribution programs since 2002 (note: $0.01 billion = $10 million)
Source: ("Infrastructure Canada", 2018)

2.3.2 Federal Funding Programs for Various Types of Projects

This section surveys the 30 federal funding programs by project type since 2002. The database used is provided by Infrastructure Canada and comprises 13,676 projects funded under 30 programs from June 2002 to February 2019. The programs in this database are earmarked (conditional), cost-sharing (matching) contribution programs, for which the federal government has some degree of involvement in the selection process. Overall, the government of Canada contributed more than $37 billion through cost-sharing programs since 2002 through Infrastructure

Canada. The projects are divided into 22 categories by Infrastructure Canada which are summarized in Figure 2-12.

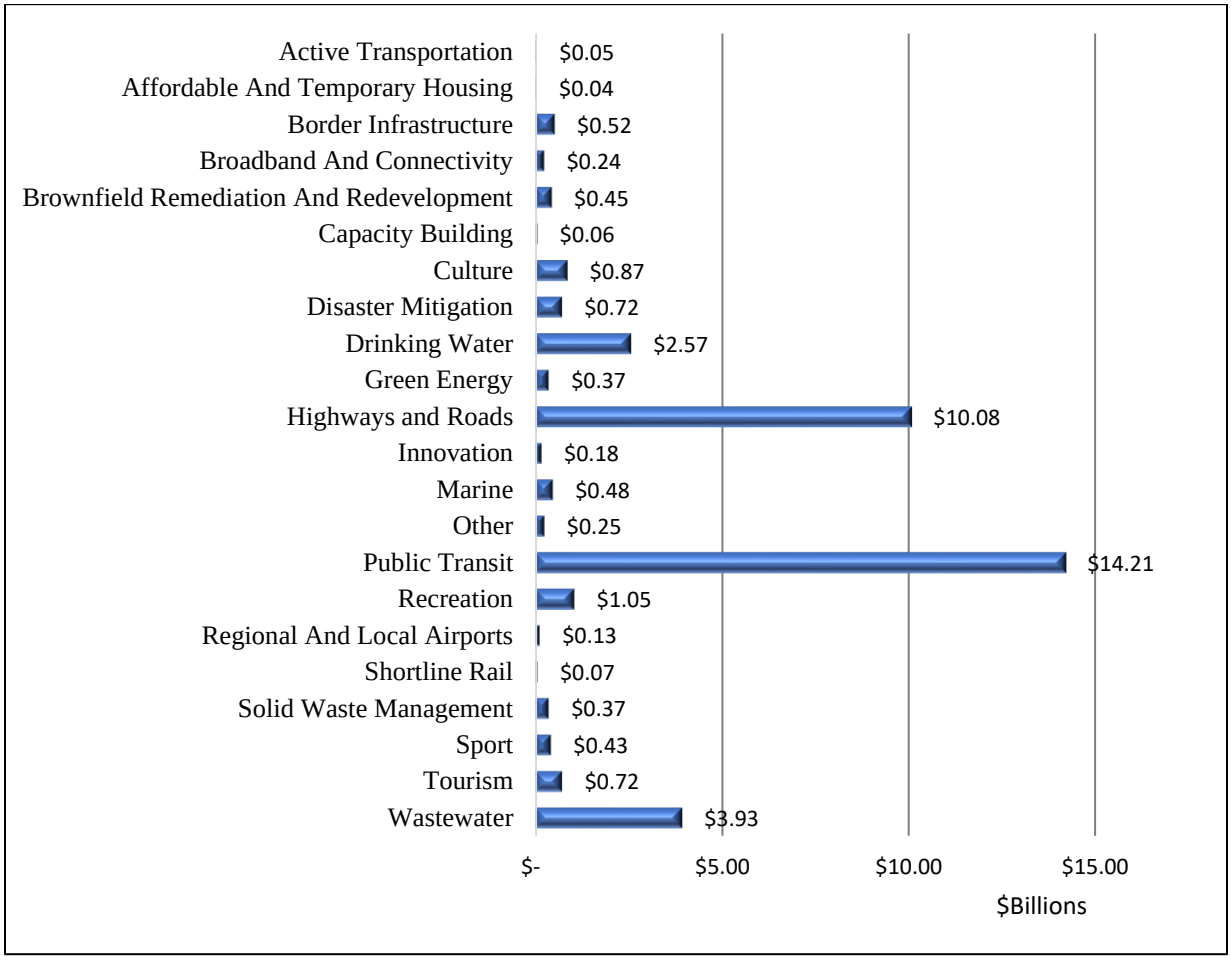

Figure 2-12 Federal contribution funding by type of project

Source: ("Infrastructure Canada", 2018)

As illustrated in Figure 2-12, approximately 70% ($26 billion) of total federal cost-sharing programs ($37 billion) is allocated to public transit, highways and roads, active transportation, border infrastructure, marine infrastructure, regional and local airports, and short-rail lines. The strong rationale behind this large amount of federal contribution is the fact that transportation projects, through movement of people and goods between jurisdictions, create positive externalities or spill-overs as well as improving productivity and economic activity. As discussed

in Section 2.2.1.3, projects that generate externalities are best financed by federal cost-sharing programs as these lower the project cost to lower levels of government and provide more incentives for these governments to spend more on such projects Moreover, investing in such productivity enhancing projects addresses both vertical and horizontal fiscal imbalances, thus meriting the federal contribution.

Investing in projects that deal with the treatment and provision of drinking water, wastewater treatment, solid waste management and green infrastructure projects encompassed more than 18% ($6.5 billion) of the total federal funding through cost-sharing programs. It is the responsibility of the federal government to provide basic amenities to promote equality of opportunity and standard of living. These projects rank second after transportation, receiving federal cost-sharing programs as the spill-over they generate is local, not inter-provincially. Perhaps, the ability to address fiscal and horizontal imbalances is the strongest argument in support of federal funding contributions to these projects.

The rest of the federal contribution is devoted to economic development projects, such as broadband and community, brownfield remediation, disaster mitigation and tourism, community and social projects including, cultural, recreational and sporting facilities, capacity building, and affordable housing. These either provide externalities at a small scale or address horizontal and fiscal imbalances, which are best financed by non-earmarked programs such as grants.

Funding innovative projects can be part of a federal strategy directed toward pursuing a national policy goal. For example, the government of Canada is leading climate change mitigation in response to Canada's ratification of the Paris Agreement. Based on the Agreement, the federal government agreed to collaborate with other nations to restrict global temperature rise to well below 2ºC by the end of century ("Infrastructure Canada", 2018).

2.3.3 Delivering Funding Programs through Contribution Agreements

Each province or territory enters into a unique agreement with the federal government on how they deliver a given program. Based on the type of program, the terms and conditions required to be fulfilled by the ultimate recipient, the duration of agreement, and the eligible recipients and projects, is different. Each province and territory is responsible to complete the agreement in a timely manner while respecting terms and conditions, funding limits, and deadlines stated in the agreement. If the corresponding province or territory is the ultimate recipient, they may enter into an Ultimate Recipient Agreement with any entity identified in the agreement that is eligible to receive contribution funding for a project.

To monitor compliance of the implementation of the agreement according to the specified terms and conditions, an oversight committee, co-chaired by representatives of the federal government and participating province or territory, is required. Usually the oversight committee meets semi-annually at a minimum.

Usually, each province and territory is required to submit to Infrastructure Canada the total amount of eligible costs incurred by the ultimate recipient (see Appendix 1 for definition) of the project at the beginning of each fiscal year, and the total amount of eligible costs incurred by the ultimate recipient of the project in the previous fiscal year. Infrastructure Canada makes payments to the participating province or territory promptly upon reviewing and approving the claim for reimbursement, subject to terms and conditions of the agreement. Depending on agreement terms and conditions, each province or territory may be required to submit progress reports, environment assessments and reports on aboriginal consultation efforts, if applicable, to receive payment from the federal government. The ultimate recipient must be able to incur and pay both eligible and

ineligible expenditures prior to submitting claims for reimbursement. A detailed description of eligible costs is provided in the next section.

Moreover, the federal government might retain a small amount of its contribution funding (e.g., up to 5%) for the Investing in Canada Plan and Small Community Funding programs until the end of the agreement period, to ensure fulfilment of recipient obligations. (This statement speaks to why senior levels of government would in general be loath to front-end loaded contributions.)

As discussed above, there is a lag between project progress and the public accounts as the payable recipients do not receive the federal contribution up-front to pay for their costs, but get reimbursed by submitting eligible costs throughout the life of the project. This means that there is a difference between the amount of money approved to be contributed to the project by federal government and the amount of money that is actually paid to the recipient (see Appendix 2). Figure 2-13 compares these two amounts in some of the federal contribution programs from 2002 to the present- day.

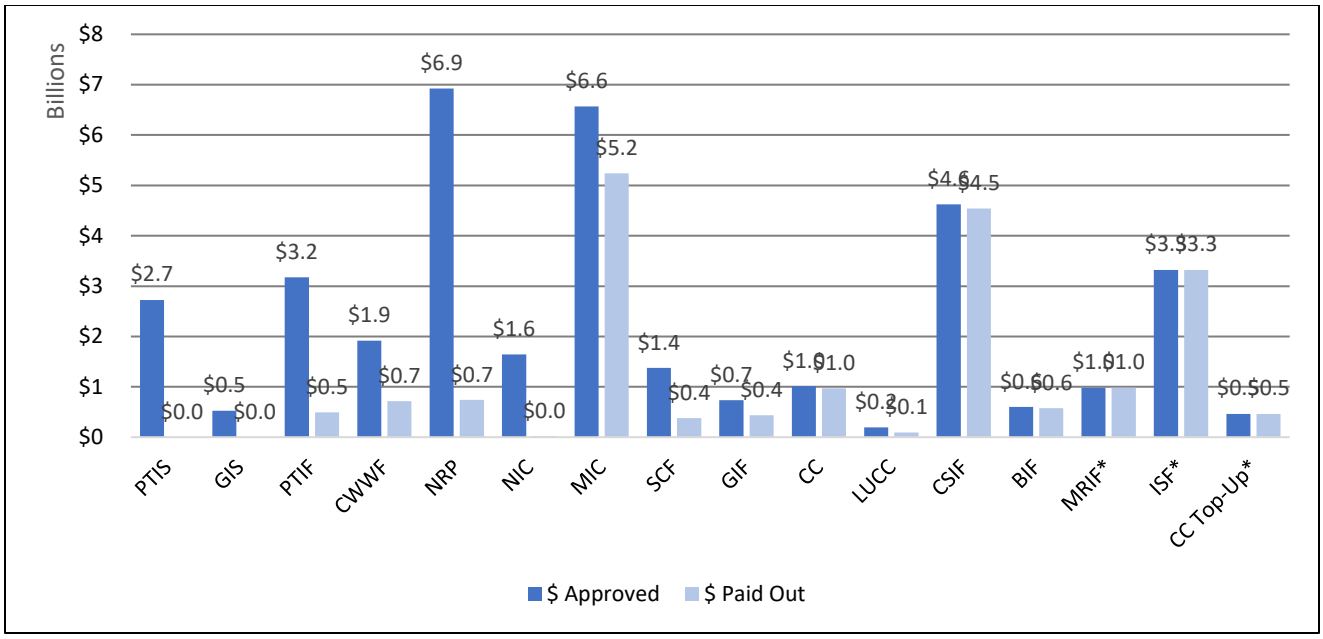

Figure 2-13 Approved vs paid to date contribution funds[4]
Source: (Infrastructure Canada Programs Overview, 2019)

Funding delays result because the reimbursement can be less than the initial committed value, but not more. This is the reason why federal contribution agreements specify that the government only contribute up to a certain percentage of total eligible expenditures and up to a maximum dollar amount. If the project costs get less than the original estimates, the contribution will be lower than planned, with respect to the original limit based on the contribution percentage. But if the project goes over the estimated costs, the maximum dollar value cap does not allow for any increase in federal funding. This condition incentivizes the project parties to control costs and allows the federal government to invest the excess money in other new projects (Jackson, 2015).

[4] Contribution funds including: Public Transit Infrastructure Stream (PTIS), Green Infrastructure Stream (GIS), Public Transit Infrastructure Fund (PTIF), Clean Water and Wastewater Fund (CWWF), New Building Canada Fund-National and Regional Projects (NRP), New Building Canada Fund-National Infrastructure Component (NIC), Building Canada Fund-Major Infrastructure Component (MIC), New Building Canada Fund-Small Communities Fund (SCF), Green Infrastructure Fund (GIF), Building Canada Fund, Communities component (CC), Canada Strategic Infrastructure Fund (CSIF), and Border Infrastructure Fund (BIF).

Another reason that funds may be delayed is with respect to unanticipated construction delays due to abnormal weather conditions, technical and other construction related issues (Transport Canada and British Columbia, 2014).

2.3.4 Eligible and Ineligible Costs

In cost-sharing programs, the federal government contributes to paying the "total eligible costs" up to a certain percentage. Eligible and ineligible costs are mostly the same across the different contribution programs. The list below summarizes the eligible and ineligible costs defined in the Investing in Canada Plan bilateral agreement between the government of Canada and British Columbia:

> *"Eligible Expenditures will include the following:*
>
> *i. All costs considered by Canada to be direct and necessary for the successful implementation of an eligible Project, excluding those explicitly identified in section A.1 e) (Ineligible Expenditures) of this Schedule, and which may include capital costs, design and planning, and costs related to meeting specific Program requirements, including completing climate lens assessments as outlined in paragraph g) of section 4 (Commitments by British Columbia) of this Agreement and creating community employment benefit plans;*
>
> *ii. British Columbia's Administrative Expenses as approved by Canada under section 16 (Administrative Expenses) of this Agreement;*
>
> *iii. The incremental costs of employees of an Ultimate Recipient may be included as Eligible Expenditures for a Project under the following conditions: a) The Ultimate*

Recipient is able to demonstrate that it is not economically feasible to tender a Contract; and b) The arrangement is approved in advance and in writing by Canada.

iv. Costs will only be eligible as of Project approval, except for costs associated with completing climate lens assessments as outlined in paragraph g) of section 4 (Commitments by British Columbia) of this Agreement, which are eligible before Project approval, but can only be paid if and when a Project is approved by Canada for contribution funding under this Agreement

Ineligible expenditures for Projects will include the following:

i. Costs Incurred before Project approval and any and all expenditures related to contracts signed prior to Project approval, except for expenditures associated with completing climate lens assessments as required under paragraph g) of section 4 (Commitments by British Columbia);

ii. Costs Incurred for cancelled Projects;

iii. Costs of relocating entire communities;

iv. Land acquisition;

v. Leasing land, buildings and other facilities; leasing equipment other than equipment directly related to the construction of the Project; real estate fees and related costs;

vi. Any overhead costs, including salaries and other employment benefits of any employees of the Ultimate Recipient, any direct or indirect operating or administrative costs of Ultimate Recipients, and more specifically any costs related to planning, engineering, architecture, supervision, management and other activities normally carried out by the Ultimate Recipient's staff, except in accordance with paragraph iii. of section A.1 c) (Eligible Expenditures) of this Schedule;

vii. Financing charges, legal fees, and loan interest payments, including those related to easements (e.g. surveys);

viii. Any goods and services costs which are received through donations or in kind;

ix. Provincial sales tax, goods and services tax, or harmonized sales tax for which the Ultimate Recipient is eligible for a rebate, and any other costs eligible for rebates;

x. Costs associated with operating expenses and regularly scheduled maintenance work;

xi. Cost related to furnishing and non-fixed assets which are not essential for the operation of the Asset/Project; and

xii. All capital costs, including site preparation and construction costs, until Canada has confirmed that environmental assessment and Aboriginal consultation obligations as required under sections 11 (Environmental Assessment) and 12 (Aboriginal Consultation) have been met and continue to be met."

The main question raised with respect to these requirements is how much would the federal government contribute relative to total project cost? In other words, what percentage of the total project cost consists of eligible costs? The answer to this question might not be straightforward as in some cases it is difficult to distinguish between eligible and ineligible costs. In an estimate conducted by Jackson (2015) based on the annual report "Transport Canada and British Columbia, 2014", in ten highways projects, approximately 75% of total costs were considered eligible.

2.3.5 Stacking and Cost-Sharing

Noted previously, under cost-sharing programs, the federal government contributes up to a certain percentage of the total eligible costs while also requiring the other parties, such as provinces, territories, municipalities, and the private sector, to cover the remaining costs. The intention is that the federal government can fund more infrastructure projects across the country and federal money is used in the most cost-effective way for taxpayers (Infrastructure Canada, 2016).

Depending on the contribution program, the allocation of stacking (i.e. using multiple source of funding to offset a portion of eligible project expenses) and cost-sharing might be different. Despite some small differences, the structure of contribution agreements is similar. For example, the federal government contributes more in projects that are provincially-owned, compared with municipal and for-profit private projects. The most likely reason is that projects in provinces can generate spill-overs, which benefit more people than projects in municipalities. On the other hand, the federal government contributes more to projects that are located in territories than in provinces in order to meet their goals related to fair distribution of goods and services, as well as in support of aboriginal populations to enhance the public welfare.

The list below summarizes cost-sharing under the 2014 New Building Canada Fund:

"*Under the 2014 New Building Canada Fund, for projects located in the provinces, the maximum federal contribution from* ***all sources*** *will be up to one-third (33.33 per cent) of the total eligible costs of a project, with the following exceptions:*

- *For projects in the highways and roads and disaster mitigation categories where the asset is* ***provincially-owned****, the maximum federal contribution* ***from all sources*** *will be up to 50 per cent of the total eligible costs.*
- *For projects in the public transit category, the maximum federal contribution* ***from all sources*** *will be up to 50 per cent of the total eligible costs.*
- *For projects where the recipient is from the for-profit private sector, the maximum federal contribution* ***from all sources*** *will be up to 25 per cent of the total eligible costs.*

For projects located in the territories, the maximum federal contribution ***from all sources*** *will be up to three-quarters (75 per cent) of the total eligible costs of a project, with the following exception:*

- *For all projects where the recipient is from the for-profit private sector, the maximum federal contribution* ***from all sources*** *will be up to 25 per cent of the total eligible costs.*"

The stacking and cost-sharing under Investing in Canada Plan is defined as below:

"Under the integrated bilateral agreements, Canada will invest up to:

- *40% of municipal* and not-for-profit projects in the provinces;*

- *50% of provincial* projects;*
- *75% for projects in the territories and for projects with Indigenous partners;*
- *25% of for-profit private sector projects (except in the Community, Culture and Recreation Stream, where for-profit private sector projects are not eligible).*

Provinces will have to cost-share on municipal projects at a minimum of 33.33% of eligible costs.

** For public transit, Canada will provide up to 50% for rehabilitation projects and up to 40% for new public transit construction and expansion projects.*

** For projects under the Rural and Northern Communities stream, Canada will invest up to 50% for provincial, municipal and not-for-profit projects, and up to 60% for municipal projects in the provinces where the municipalities have a population of less than 5,000."*

2.4 Summary

In this chapter, funding sources for municipal infrastructure projects, different types of federal contribution programs along with the economic rationale and motivations of the federal involvement in financing municipal and provincial infrastructure were discussed in detail. In the following Chapter, the effect of contribution agreement terms (timing of the contribution, the eligibility, and the cost-sharing ratio) are explored in terms of their consequences for the ultimate recipient, the government making the contribution, and end users. It is noted that no government policy documents nor scholarly references were found regarding the setting of these terms and their impacts on project performance from different participant perspectives.

Chapter 3: Modeling Senior Level of Government Contribution Strategies

As discussed in Chapter 1, infrastructure is owned by any of the three levels of government: federal, provincial or municipal. Depending on the choice of procurement mode to finance and deliver an infrastructure project and the level of government that owns the infrastructure, the sources of funding to cover the capital cost of the project can be different. Capital costs are any cost which is directly attributable to the acquisition, construction or development of an infrastructure project including: design, construction, commissioning, and interest either paid or capitalized during the design and construction phase. Figures 3-1 to 3-3 show general cash flow models from the perspective of the overall project, i.e., all flows are shown which include the flows of money from project participants (compare to a cash flow diagram from a particular participant perspective). As illustrated in the figures, given a procurement mode, there are three potential sources of funding for financing the capital cost of an infrastructure project:

the client: the client can be the federal, provincial or municipal government; the primary focus herein is on a municipal or provincial government client.

- the senior level of government: if the client is a municipality, the senior level of government is either the federal or provincial government or both. When the province is the client, the senior level of government is the federal government, and
- the contractor or private sector: they finance the capital cost of the project wholly or partially either on a short-term or long-term basis as a function of procurement mode.

These figures are based on the assumption that the project is a municipal one, the senior levels of government are both federal and provincial, and depending on procurement mode, the contractor or private sector may participate in financing as well as providing design and or construction services. The Y axis represents the dollar value of flows and the X axis is the

timeline where the unit of the time is a month. Time zero is assumed to be when need and associated parameters for the project have been determined, a business case prepared, and a decision taken to proceed with the project. The assumption is made that there is a one-month time lag between incurring costs for design and construction services and payment for these services, either through direct payment from the client or via loan drawdown. The capital cost which needs to be financed by project participants includes design, construction and interest paid or capitalized during the design and construction phase. Senior levels of government make milestone contribution payments through the design and construction phase. Note that the federal and provincial contributions, if made, are not necessarily coupled, i.e., each government determines the rule set that guides its contribution amount and payment pattern. Any financing deficiencies are covered by the municipal debt and private sector debt and equity drawdown according to a specified ratio. Under the DBB procurement mode, the capital cost of the project is funded by municipal debt and federal and provincial contributions. Under DBF and DBFOM procurement modes, a portion of the capital cost is also financed by private sector debt and equity. In the case of DBF, the private sector is repaid the capital cost financed along with the finance charges a short period after substantial project completion. However, under the DBFOM the private sector is repaid throughout the operation and maintenance phase.

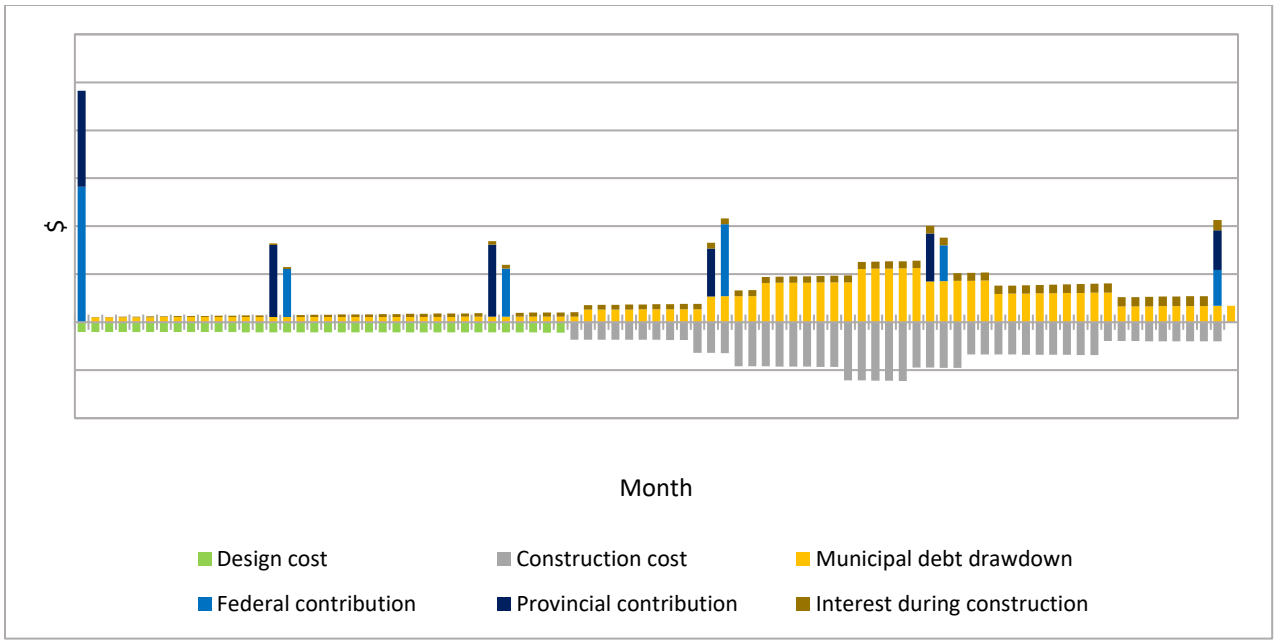

Figure 3-1 Project cash flow diagram under DBB (Design-Bid-Build) procurement mode

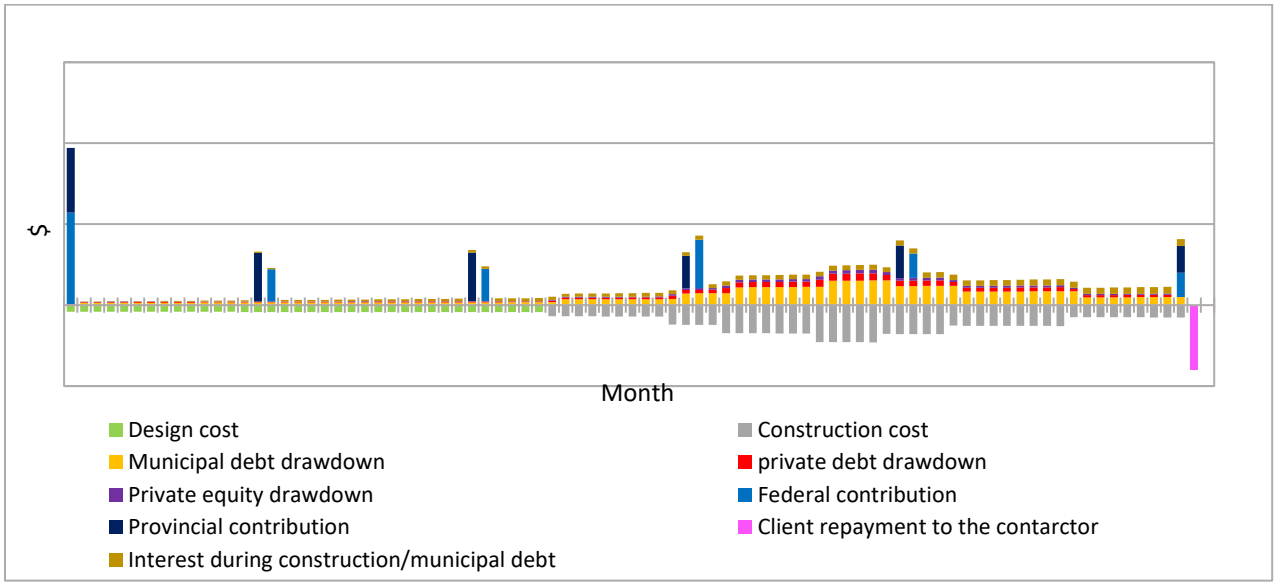

Figure 3-2 Project cash flow diagram under DBF (Design-Build-Finance) procurement mode

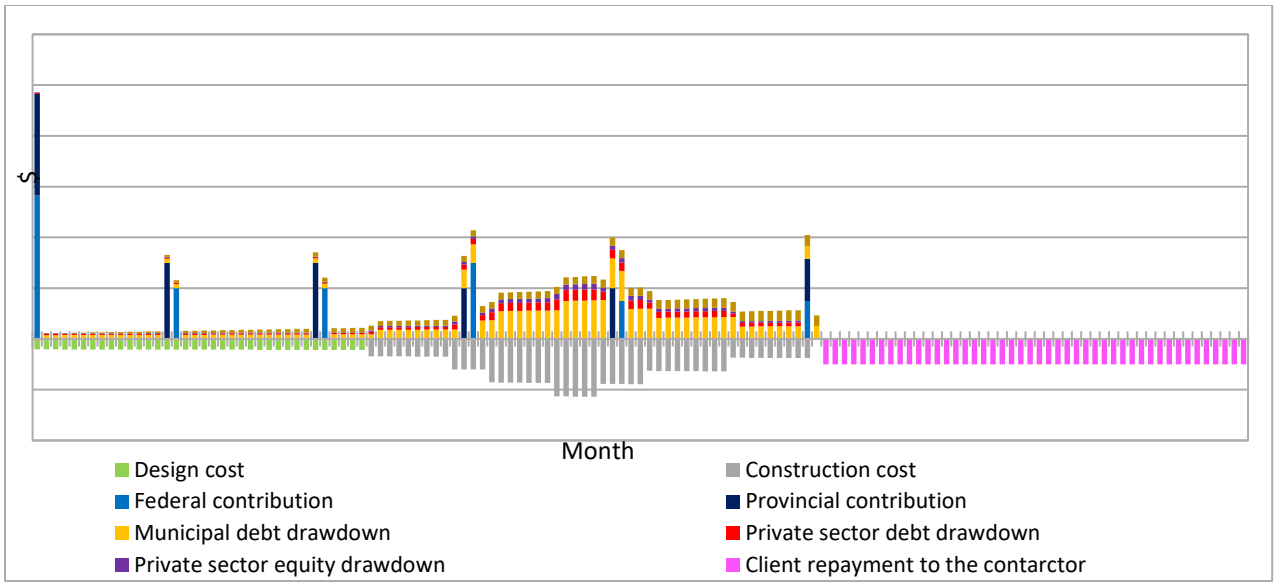

Figure 3-3 Project cash flow diagram under DBFOM (Design-Build-Finance-Operate-Maintain)

The primary goal of Chapters 3 and 4 is to explore the sensitivity of project participant objectives and related performance metrics to the terms of the contribution agreements for different procurement modes. The terms of particular interest are:

- the timing of contribution payments – i.e. the times at which the client receives contribution payments from the senior government.
- the cost-sharing ratio – i.e. the amount of the contribution payment as a percentage of total capital cost, and
- the eligibility ratio, a percentage of total capital cost which is eligible for senior government contribution.

Fundamentally, the question to which answers are sought is "Do variations in the foregoing terms really matter, and from whose perspective?"

Performance metrics are used to quantify objectives of the client, the senior level(s) of government, the private sector delivery team, and end users. As stated previously, procurement modes examined

are DBB, DBF, and DBFOM. Tables 3-1 to 3-4 list the objectives of the project participants. These are elaborated under procurement mode headings to identify their specific definition under each procurement mode and the performance metrics that may be used to estimate the level to which the goals are met. Not all performance metrics of potential interest are included, especially if one wished to measure relative effectiveness of different procurement modes, which is not the goal herein. As an example, life cycle cost is not treated.

It is observed that there can be conflict between objectives and corresponding metrics for a specific participant viewpoint and between participant viewpoints. An example of the former is the senior level of government desire to stimulate investment in infrastructure at the provincial and municipal levels (which can be aided by front-end loaded contribution payments) versus its desire to ensure full compliance with all regulatory and environmental requirements (hence postpone contribution payments until later). An example of the second is minimization of interest payments. For the recipient of contribution payments, receipt of money as early as possible is best. For the senior government providing the payments, providing contribution payments as late as possible is best (the assumption being that senior government contributions are debt financed). The challenge becomes one of reconciling potentially conflicting objectives for a given participant viewpoint and between participant viewpoints. While flagged as an important issue, and one that explains in part how participants behave, how best to reconcile objectives within and between participant viewpoints and establish relevant policy is beyond the scope of this thesis.

Objective	DBB	DBF	DBFOM
Minimize cost	• Capital costs ○ Design ○ Construction[5] ○ Interest expense during design and construction phase, IDC ▪ Public client debt	• Capital costs ○ Design ○ Construction ○ Interest expense paid or capitalized during design and construction phase, IDC ▪ Public client debt ▪ Private sector debt	• Capital costs ○ Design ○ Construction ○ Interest expense paid or capitalized during design and construction phase, IDC ▪ Public client debt ▪ Private sector debt
Provide affordable services for end users	User fees, taxation level, and subsidy level required to pay for the infrastructure		
Provide reliable and high-quality services	While in theory the performance metric values are the same across all procurement modes for the same project, the incentivization to achieve this objective differs as a function of procurement mode, hence performance may be different. The relative performance of different procurement modes is not addressed in this study.		
Provide on-time and on-budget project completion Speed of delivery can be important	While in theory the performance metric values (e.g. overrun values) are the same across all procurement modes for the same project, the incentivization for on-time and on-budget completion differs as a function of procurement mode. The relative performance of different procurement modes is not addressed in this study. Incentivization increases from left to right →		

[5] Construction cost is defined to include commissioning cost.

Provide for innovation and cost efficiency	The opportunity for pursuing innovation and developing cost efficient solutions resulting from the integrated treatment of project phases and ability to forge trade-off between capital and future costs differs as a function of procurement mode. This issue is not addressed in this study. Opportunity for innovation and cost efficiency increases from left to right →
Minimize risk	The opportunity of transferring risk to the provide sector differs as a function of procurement mode. This issue is not addressed in this study. Opportunity for transferring risk to private sector increases from left to right →

Table 3-1 Client objectives

Objective	DBB	DBF	DBFOM
Minimize the interest expense during the design and construction phases	Interest expense on debt during the design and construction phases		
Contribute up to a percentage of total eligible costs and up to a maximum dollar value	In case of front-end loaded contributions, the senior level of government contribution would be based on an estimate of costs. While in case of back-end loaded contributions, the contribution would be based on actual costs. There is a probability that actual cost may be lower than estimated costs, although experience suggests that overruns are more common. An expression of the performance metric is that the senior level of government commitment is bounded.		
Bound what qualifies as an eligible cost	The eligibility rules are the same across all procurement modes. However, the magnitude of contribution can be a function of the procurement mode. It is not addressed in this study.		
Maximize speed of delivery	The incentivization for speeding the delivery of project differs as a function of procurement. This issue is not addressed in this study. Incentivization increases from left to right →		
Assure compliance with all regulatory requirements	Same regulatory requirements apply across all procurement modes. Not Applicable		
Maximize transparency and accountability	Applicable to all procurement modes – not considered		
Provide a long-term infrastructure investment plan and incentivize its pursuit by all levels of government	A function of project type verses the procurement mode. Not Applicable		
Foster economic growth			
Create Jobs			

Table 3-2 Senior levels of government objectives

Objective	DBB	DBF	DBFOM
Minimize the interest expense during the design and construction phases	Not applicable	Interest capitalized during the design and construction phases	
Maximize profitability of project: profit earned on provision of design and construction services, return on capital employed	Profit for design and construction services: Price minus cost	Maximize price minus cost of design & construction services; Minimize interim financing charges; Maximize return on any equity capital used (IRR)[6] subject to NPV ≥ 0 at required MARR[7]; All of the foregoing conditioned by the need to achieve a compliant and winning bid	Maximize price minus cost of design & construction services; Minimize life cycle costs at concessionaire discount rate Maximize return on equity capital used (IRR) subject to NPV ≥ 0 at required MARR; All of the foregoing conditioned by the need to achieve a compliant and winning bid
Maintain Annual debt service coverage ratio above the threshold required by the lending agency, $DSCR > DSCR_{min}$	Not Applicable	The DSCR refers to the ratio of a contractor's cash available for debt servicing to its annual principal and interest payments (may not be applicable to DBF).	The DSCR refers to the ratio of a concessionaire's cash available for debt servicing to its annual principal and interest payments.

Table 3-3 Delivery team or private sector objectives

[6] Internal Rate of Return, IRR, is used to measure the return of an investment. It is a discount rate that makes the NPV of a project equal to zero.

[7] Minimum Acceptable Rate of Return, MARR, is the minimum rate of return that an investor expects to earn from an investment. The project is not economically viable if the project rate of return is less than MARR.

Objective	DBB	DBF	DBFOM
Minimize unit life cycle cost	User fee and/or taxation level		
Maximize reliability and quality of services	While in theory the performance metric(s) values are the same across all procurement modes for the same project, the incentivization differs as a function of procurement mode, hence performance may be different. This issue is not addressed in this study.		
Maximize stability in unit cost over time	Not Applicable		

Table 3-4 End-user objectives

Several of the objectives listed in Tables 3-1 to 3-4 are defined similarly for the three procurement modes examined. However, each procurement mode may provide different incentivization and opportunity for the project proponents to maximize performance metric values. Those objectives which are neither impacted by the terms of the contribution agreement nor by choice of procurement modes are defined as Not Applicable, but are included in Table 3-1 to 3-4 for purposes of completeness. While the issue of comparing procurement modes in terms of their effectiveness for maximizing stakeholder values is beyond the scope of this study, this thesis lays useful ground work for extending the model to support the decision-making process of determining which procurement mode best achieves client objectives.

The cash flow model presented in this chapter measures how changes in contribution agreement terms affect project proponent objectives for the procurement modes examined. Based on the objectives presented in Tables 3-1 to 3-4, items which are measured by the model are:

- total project cost incurred by the client including: design and construction costs and interest expense (paid or capitalized) during design and construction phases.
- interest expense during the design and construction phases from the viewpoint of client, senior levels of government and private sector.

While design and construction costs are a function of project type, scale, and procurement mode, the interest expense during design and construction phase depends on the terms of the contribution agreement as well as on the choice of procurement mode.

In order to measure the sensitivity of the objectives to contribution agreement terms, the cash flow model is formulated from the perspectives of each project participant. Given a procurement mode, there are different cash flow structures which reflect the project participants' responsibility in financing the capital cost of the project (Figures 3-1 to 3-3).

Summarized in Table 3-5 are the parameters and variables used in the model to make it as general as possible and their relevance to each procurement mode examined. Several of these identified are only relevant if one seeks to choose amongst procurement modes.

Name	Symbol	Unit or reported as	Description	DBB	DBF	DBFOM
Degree of acceleration during the construction phase	A_C	%	Degree of improvement in the speed of construction phase delivery, where $a_{Cl} \leq A_C \leq \leq a_{Cu}$. A negative value for a_{Cl} (lower bound) means that the construction phase is to be slowed (e.g., this happens when there are financing constraints). An upper bound value of a_{Cu}=1 means that an already constructed facility is purchased.	✓	✓	✓
Degree of acceleration during the design phase	A_D	%	Degree of improvement in speed of design phase delivery, where $a_{Dl} \leq A_D \leq a_{Du}$. A negative value for a_{Cl} (lower bound) means that the design process is extended out (e.g., this happens when there are insufficient design resources, or when decision-making by the client is slow). An upper bound value of a_{Cu} =1 means that a completed design is purchased.	✓	✓	✓
Constant dollar cumulative construction cost	C_{C0}[8]	$	Cumulative constant dollar construction cost measured as of time zero.	✓	✓	✓
Current dollar cumulative construction cost	C_C	$	Cumulative current dollar construction cost that captures price movement during the design and construction phase.	✓	✓	✓

[8] Time zero reflects time when the constant dollar costs are estimated.

Constant dollar construction expenditure at time t	$c_{C0}(t)$	$	Constant dollar construction expenditure rate throughout the construction phase measured in time zero dollars.	✓	✓	✓
Current dollar construction expenditure at time t	$c_C(t)$	$	Current dollar construction expenditure rate throughout the construction phase.	✓	✓	✓
Constant dollar cumulative design cost	C_{D0}	$	Constant dollar cost of design expressed in time zero dollars.	✓	✓	✓
Current dollar cumulative design cost	C_D	$	Current dollar cost of design.	✓	✓	✓
Constant dollar design expenditure at time t	$c_{D0}(t)$	$	Constant dollar expenditure rate for design services.	✓	✓	✓
Current dollar design expenditure at time t	$c_D(t)$	$	Current dollar expenditure rate for design services.	✓	✓	✓
Municipal debt financing at time t	$d_M(t)$	$	Debt drawdown rate in current dollars by municipal government at any given time throughout the project	✓	✓	✓
Private sector debt financing at time t	$d_P(t)$	$	Debt drawdown rate in current dollars by private sector at any given time throughout the project.	✓	✓	✓
Constant dollar expenditure ratio during construction phase at time t	$exp_{C_0}(t)$	%	The ratio of construction constant dollar expenditure rate at any given point of time during construction to cumulative constant dollar construction cost. $$exp_{C_0}(t) = \frac{c_{C_0}(t)}{C_{C_0}}$$	✓	✓	✓
Constant dollar expenditure ratio during design phase at time t	$exp_{D_0}(t)$	%	The ratio of design constant dollar expenditure rate at any given point in time to constant dollar design cost. $$exp_{D_0}(t) = \frac{c_{D_0}(t)}{C_{D_0}}$$	✓	✓	✓

Private sector equity expenditure at time *t*	$e_P(t)$	$	Equity expenditure rate incurred by the private sector at any given time throughout the project.		✓	✓
Degree of overlap between design and construction phases	F	%	F represents the degree of fast-tracking – i.e., concurrent design and construction, where, $f_l \leq F \leq f_u$, such that start of construction = (1-F) *T_D. A negative value of f_l (lower bound) means that there is a lag between completion of the design and construction phases.		✓	✓
Federal contribution at time *t*	$f(t)$	$	Contribution rate of funds injected into the project by the federal government during the project development phase.	✓	✓	✓
Federal cumulative interest paid during the design and construction phases	IDC_F	$	Cumulative interest paid on federal debt during the design and construction phases.	✓	✓	✓
Municipal cumulative interest paid during the design and construction phases	IDC_M	$	Cumulative interest paid on municipal debt during the design and construction phases.	✓	✓	✓
Private sector cumulative interest paid during design and construction phases	IDC_P	$	Interest accumulated on private sector debt until the time the private sector receives repayment from the client to service the debt.		✓	✓
Provincial cumulative interest paid during design + construction phase	IDC_{PR}	$	Interest paid on provincial contribution during the design and construction phases.	✓	✓	✓
Federal interest paid during design and construction phases at time *t*	$idc_F(t)$	$	Interest paid on federal cumulative debt up until any given time during design and construction phases.	✓	✓	✓
Municipal interest payment during design and construction phases at time *t*	$idc_M(t)$	$	Interest paid on municipal cumulative debt up until any given time during the design and construction phases.	✓	✓	✓

Provincial interest payment during design and construction phases at time *t*	$idc_{PR}(t)$	$	Interest paid on provincial cumulative debt until any given time during the design and construction phases.	✓	✓	✓
Federal effective monthly interest rate	i_F	%	Cost of borrowing for the federal government – assumed to be invariant with time.	✓	✓	✓
Municipal effective monthly interest rate	i_M	%	Cost of borrowing for the municipal government – assumed to be invariant with time.	✓	✓	✓
Municipal effective monthly short-term investment interest rate	$i_{Mshorterm}$	%	Interest earning power of municipal government	✓	✓	✓
Private sector effective monthly interest rate	i_P	%	Cost of borrowing for the private sector – assumed to be invariant with time.		✓	✓
Provincial effective monthly interest rate	i_{PR}	%	Cost of borrowing for the provincial government – assumed to be invariant with time.	✓	✓	✓
Interest income at time *t*	$ininc(t)$	$	Interest earned by the client on the unallocated senior government contribution.	✓	✓	✓
Provincial contribution at time *t*	$p(t)$	$	Funds injected into the project by the provincial government at any given time throughout the development phase.	✓	✓	✓
Private sector equity ratio	r_{e_P}	%	The ratio of design and construction costs after deduction of senior government contribution payments (inclusive of interest earned on early payments) financed by private sector equity, to total design and construction costs.		✓	✓
Eligibility ratio	r_{el}	%	The ratio of total capital cost eligible for the senior government contribution to total capital cost.	✓	✓	✓

Municipal debt ratio	r_{d_M}	%	The ratio of design and construction costs after deduction of senior government contribution payments (inclusive of interest earned on early payments) financed by the municipal government debt, to total design and construction costs.	✓	✓	✓
Private sector debt ratio	r_{d_P}	%	The ratio of design and construction costs after deduction of senior government contribution payments (inclusive of interest earned on early payments) financed by private sector debt, to total design and construction costs.		✓	✓
Federal contribution ratio	R_F	%	The ratio of federal government contribution to total eligible capital cost.	✓	✓	✓
Provincial contribution ratio	R_{PR}	%	The ratio of provincial government contribution to total eligible capital cost.	✓	✓	✓
Federal contribution ratio at time *t*	$r_F(t)$	%	The fraction of R_F used to determine the federal contribution payment at time t.	✓	✓	✓
Provincial contribution ratio at time *t*	$r_{PR}(t)$	%	The fraction of R_{PR} used to determine the provincial contribution payment at time t.	✓	✓	✓
Unissued senior government contribution at time *t*	$uisc(t)$	$	The amount of the senior government contribution money which is not issued yet by the client at any given time throughout the project.	✓	✓	✓
Issued senior government contribution at time *t*	$isc(t)$	$	The amount of the senior government contribution money issued by the client to finance the design and construction costs at time t.	✓	✓	✓
Construction period under normal conditions	T_{Cb}	month	Duration of the construction phase under an un-accelerated condition.	✓	✓	✓

Construction period	T_C	month	Duration of the construction phase inclusive of any acceleration efforts: $T_C = (1\text{-}A_C) * T_{Cb}$	✓	✓	✓
Design period under normal conditions	T_{Db}	month	Duration of the design phase under an un-accelerated condition.	✓	✓	✓
Design period	T_D	month	Duration of the design phase inclusive of any efforts to accelerate design: $T_D = (1\text{-}A_D) * T_D$	✓	✓	✓
Cumulative total capital cost	TC	$	Cumulative total capital cost inclusive of design and construction costs and interest capitalized or paid during the design and construction phases.	✓	✓	✓
Total senior contribution at time *t*	$tsc(t)$	$	Total senior government contribution money plus interest income and funds that were not issued in the most previous time period from last period up to time t.	✓	✓	✓
Total Project cost	TPC	$	Total project cost inclusive of design and construction costs, interest paid or capitalized on project participants' debt, i.e., the federal, provincial, and municipal government, and private sector.			
Total project cost incurred by municipal government	TPC_M	$	Total project incurred by the municipal government, inclusive of portion of design and construction costs financed by municipal government borrowing, interest paid on municipal government debt during design and construction, and interest accumulated on private sector debt during design and construction phases.			
Inflation effective monthly rate	θ	%	The rate at which the average price of a basket of construction related goods or services increases or decreases.	✓	✓	✓

Table 3-5 Model variables and parameters

3.1 Model Assumptions

Assumptions made in developing the parameterized cash flow model are:

1. The focus is on exploring the sensitivity of performance metrics for participant objectives to contribution agreement terms under different procurement modes. This thesis is not concerned with an inter-comparison of procurement modes in terms of their relative effectiveness to achieve a certain objective. Therefore, for purposes of simplicity, the project cost and time are assumed to be the same under all procurement modes examined. Nevertheless, the generality of the parameterized cash flow model developed allows for a broader range of performance metrics and accompanying objectives to be explored.
2. Discrete end-of-period cash flow modeling has been used because of its familiarity to readers. Identical and relatively simple cash flow shape functions have been used for design and construction expenditures for all procurement modes. It is observed that such shape functions are dependent on project type and execution strategy as a function of procurement mode. Greater generality could be achieved via continuous modeling, but it is not required for the specific objectives of this thesis.
3. Cash flow modeling is conducted only for design and construction phases.
4. It is assumed that any cash inflow or outflow occurs at the end of each month.
5. In the model, and as observed from Table 3-5, capital letters are used to denote cumulative cash flows and lower-case letters are used for cash flows per period. Moreover, the subscript of 0 (zero) is used to express either cumulative cash flows or cash flows in terms of constant or real dollars, while the absence of the subscript refers to current or nominal dollars.

6. The client payments to the contactor generally lag the contractor expenditures by 30 to 60 days (and in some cases 90 days). A lag time of 1 month has been assumed throughout the model.
7. It is important to accurately assess all participant cash flows as well a total capital cost. This is essential to the effective management of project funding sources including senior government contributions and debt and equity drawdowns. During the capital expenditure phase of the project, having an accurate cash flow estimate is imperative in order to know how much financing is needed at a given time. Any excess funding sources, i.e. money which is available but has not been spent yet, is assumed to be invested in an interest earning account until such time as it is needed to assist with project financing. In addition, having an accurate cash flow estimate plays a vital role in the client's ability to avoid incurring extra financing fees from borrowing money or using precious equity funds either because less money might be required for a time period that was initially estimated, or more money might be needed than what was initially forecast. We assume that the design expenditure function is modeled via a uniform cash flow, as during the design phase the level of resources required to manage the project or the expenditure rate is fairly the same. For simplicity, design fees have not been divided into detailed design and design field services, with the latter occurring during the construction phase. During the construction phase, construction expenditures are assumed to start slowly, ramp-up substantially, plateau, and then decrease gradually until the end of construction phase.
8. It is assumed that the client ('the ultimate recipient') of the project is a municipal government. Therefore, the senior levels of government are federal and provincial.

9. The contribution payments from senior levels of government can be paid to the client as a single front-end loaded payment at the start of the project, or a back-end loaded payment, at the end of construction period, or they can be distributed as multiple milestone payments at the end of each milestone month. For the purpose of this thesis, in order to examine the two extremes of contribution timing and bound performance, only front-end loaded and back-end loaded payments are considered in the case study application in Chapter 4. From a municipal perspective, in order of preference, a front-end loaded contribution is preferred to intermediate milestone payments which are preferred to a back-end loaded payment. One can make the case that the opposite is preferred by senior government levels if the focus is only on the cost to the senior level of government and incentivization of good performance (time, cost, compliance with all regulations, etc.).
10. Payments from the federal and provincial governments to the client do not necessarily follow the rate of expenditure incurred by the client. For example, the senior level of government may contribute all of their share before construction begins (referred to as a front-end loaded contribution). In such a case, it is assumed that the municipal government manages the money to leverage its interest-earning power, i.e., any excess contribution funded in any given month can be invested in an interest-earning account until needed to assist the municipality in financing the project.
11. In terms of the order of making drawdowns on financing sources, it is assumed that the client gives priority to contribution payments from federal and provincial governments and the interest income on un-used contribution funds. Therefore, the client allows the private sector to defer his/her commitment in financing until the total senior contribution is used up. (This assumption does not capture the benefit that the financial institution oversight

could bring at the beginning of the project. For more realistic cash flow analysis, the model could be adapted to allow for the ability to specify the input profile for private sector financing.) Any financing shortfalls are covered by the municipal debt financing and private sector debt and equity financing according to pre-specified ratios as a function of procurement mode.

12. The capital cost of an infrastructure project consists of: land acquisition, procurement management, design, legal fees and administration, overhead and utilities, interest during construction, and construction and commissioning. In this thesis, the primary focus is on a subset of capital costs including design, construction and commissioning and interest during construction which are incurred by the client after the senior government contribution approval and may be eligible for contribution agreements. Therefore, in this thesis, when referring to capital costs, this means the subset of capital costs identified above.
13. Not all of the total amount of the capital costs of a project are considered eligible for federal contribution. Eligibility constraints on cost items vary from one contribution program to another. Here, for the purpose of simplicity, the eligibility constraint is based on a specified percentage of total capital cost.
14. The financing costs which are incurred by the municipal, provincial, and federal governments are not eligible for senior government contribution. However, for the DBF and DBFOM procurement modes, the private sector financing costs are considered as an eligible cost because the interest capitalized during design and construction phases is part of project capital costs and consequently is a part of the bid price that the private sector submits to the client.

15. The interest rate at which the public sector borrows money differs among the levels of government. Cost of borrowing depends on variations between the credit ratings of the municipalities, the provinces and the federal government. Table 3-6 provides an example of average interest rates that different levels of government, Toronto (municipal), Ontario (provincial) and Canada (federal), have borrowed at between 2008 until 2014.

Borrower	Mean	Moody's Rating
Toronto	3.96	Aa1
Ontario	3.59	Aa2
Canada	2.70	Aaa

Table 3-6 Interest rates on bonds for selected province and city, 2008-2014
Source: (Hanniman, 2015)

As illustrated in Table 3-6, on average the federal government borrows money at rates that are approximately 1.26 percentage points (126 basis points) lower than Toronto and 0.9 percentage points (90 basis points) lower than Ontario's provincial financing authorities.

16. While interest during construction for private sector financing is capitalized and paid after project completion, it is assumed that interest during construction for all three levels of government is considered as an on-going expense and is paid at each month as they defer the payment of debt on an indefinite basis.
17. The opportunity to accelerate the delivery of a project varies by the type of procurement mode. Shortening the project delivery time can be undertaken either through overlapping between design and construction phases or accelerating the design phase or construction phase or a combination of these. Since this research does not explore the inter-comparison of different procurement modes in terms of effectiveness to fulfil the project participant's

objectives, it is assumed that the degree of overlapping between design and construction phases, degree of acceleration of the design phase, and degree of acceleration of the construction cost, F, A_D, and A_C, respectively, are equal to zero.

18. It is assumed that the inflation rate, and all interest rates used in the model are constant over time.

In Section 3.2, a parameterized cash flow model is developed to simulate the capital expenditure flows, i.e., design, construction and interest expense during design and construction, as well as financing flows, i.e., the client debt financing, the senior levels of government contribution payments, interest earned during design and construction phases by the client if applicable, and the private sector debt financing during design and construction phases. The model developed in Section 3.2 is a general cash flow model and the terms and parameters used in the model can be tailored according to model assumptions and the choice of procurement mode.

Use of the model allows one to measure the interest expense (paid or capitalized) during the design and construction phase from the perspective of the client, the senior levels of government, and the private sector and total project cost from the viewpoint of the client. Once the aforementioned performance metrics are calculated, one can explore the sensitivity of them to changes in the terms of the contribution agreement.

3.2 Cash Flow Model

In order to compute the performance metrics of interest, it is imperative to distinguish between the perspective of the project and the perspective of individual project participants, i.e., the client, the senior government, and the private sector delivery team. Equation (1) shows the total cost from

the perspective of the project with each project participant financing a portion of it – i.e., the total capital cost of the project inclusive of financing costs incurred by project participants:

$$TPC = C_D + C_C + IDC_P + IDC_M + IDC_{PR} + IDC_F \quad (1)$$

in which C_D *and* C_C are design and construction costs in current dollars, respectively, and IDC_P, IDC_M, IDC_{PR}, and IDC_F are financing costs from the perspectives of the private sector, the client or the municipal government, and the provincial and federal governments, respectively.

To calculate the project cost from a particular participant's perspective, the capital equation will be different. For example, from the perspective of the senior government eligibility rules and policy, the financing cost on municipal debt is not eligible for government contribution, while the financing cost of the private sector is considered eligible as it is a part of the project capital cost. On the other hand, from the viewpoint of the client, the financing costs incurred by the federal and provincial government (as well as the actual value of the contribution) are not a cost but rather is considered a "gift" or grant to them. The primary perspective of interest herein is that of the client. The project cost from the viewpoint of the municipal government after the senior government contribution, the first performance metric, is calculated by Equation (2):

$$TPC_M = \sum_{t=2}^{[(1-F)*T_D+T_C]+1} d_M(t) + IDC_P + IDC_M \quad (2)$$

F, A_D, and A_C are the degree of overlapping between design and construction phases, degree of acceleration of the design phase, and degree of acceleration of the construction phases,

respectively. They are incorporated into the model to undertake the opportunity to accelerate the delivery of a project through overlapping between design and construction phases or accelerating the design phase or construction phase or a combination of these. Thus,

$$T_D = (1 - A_D) * T_{Db} \tag{3}$$

$$T_C = (1 - A_C) * T_{Cb} \tag{4}$$

and,

$$T_D + T_C = (1 - F) * (1 - A_D) * T_{Db} + (1 - A_C) * T_{Cb} = (1 - F) * T_D + T_C \tag{5}$$

in which, T_{Db} and T_{Cb} are the design and construction periods, respectively, under normal condition, i.e., no accelerating or overlapping. The opportunity to accelerate the delivery of a project varies by the type of procurement modes. Since this research does not explore the inter-comparison of different procurement modes in terms of effectiveness to fulfil the project participant's objectives, it is assumed that F, A_D, and A_C are equal to zero.

The municipal debt drawdowns in each month are $d_M(t)$. Since the drawdowns of municipal government loan payments are made with a one-month lag time, i.e., for month *t*+1, the municipal government is required to make a loan drawdown for the cost incurred in month *t*, the summation of $d_M(t)$ starts from month 2 until the month $[\ (1 - F) * T_D + T_C] + 1$, when the municipal government pays for the cost incurred in the month $[\ (1 - F) * T_D + T_C]$.

The second performance metric is the IDC from the perspective of each project participant. Since the objective of this study is to explore the sensitivity of performance metrics to the terms of contribution agreements, the project capital cost which is potentially eligible for senior government contribution is calculated. Equation (6) defines the total capital cost during the design and

construction phase inclusive of private sector financing charges, TC, required to be financed by all project participants:

$$TC = C_D + C_C + IDC_P \tag{6}$$

For generality, the estimates of design and construction costs should be first made in terms of constant or real dollars (prices benchmarked against a particular point in time). Once the timing of design and construction flows are estimated, the adjustment for price movement may be made. The underlying rationale behind this notion is that it considers the influence of inflation on current dollar costs because the speed of project delivery is explicitly accounted for in the model. For example, if one procurement mode is faster than another, then it can lead to lower design or construction costs and possibly interest costs. While the study of the inter-comparison of procurement modes is beyond the scope of this research, this feature of the model allows it to be extended to support the selection of a preferred procurement mode.

It is important to note that from a financing perspective, it is the current dollar expenditures that are financed. This forces one to incorporate the inflation rate in the expenditure functions of Equations (4) and (5) to account for price movement, unless current dollar costs are estimated directly.

Equations (7) and (8) show the cumulative design and construction cost in constant dollars expressed both in local (τ) and global (t) coordinates. For purposes of consistency, all equations later will be expressed in global coordinates. From a practical viewpoint, it is most useful to first express shape functions in local coordinates and then transform to global coordinates. This is not undertaken here.

$$C_{D0} = \sum_{\tau=1}^{(1-A_D)*T_{Db}} c_{D_0}(\tau) = \sum_{t=1}^{(1-A_{D)*}T_{Db}} c_{D_0}(t) \; in\, which\; t = \tau \tag{7}$$

$$C_{C0} = \sum_{\tau=1}^{(1-A_C)*T_{Cb}} c_{C_0}(\tau) = \sum_{t=(1-F)*T_D}^{(1-F)*T_D+(1-A_C)*T_{Cb}} c_{C_0}(t) \;\; in\, which\; t = \tau + (1-F)*T_D \tag{8}$$

In Equations (7) and (8), $c_{D_0}(t)$ and $c_{C_0}(t)$ are constant dollar design and construction flows in each month *t* on the project time axis. Equation (8) demonstrates the use of both a local coordinate system (τ) and a global coordinate system (t). The magnitude of each constant dollar flow is calculated by multiplying its cumulative amount by expenditure rate in each month:

$$c_{D_0}(t) = C_{D0} * exp_{D_0}(t) \tag{9}$$

$$c_{C0}(t) = C_{C0} * exp_{C_0}(t) \tag{10}$$

Thus, one starts with the general shape function $exp_{X_0}(t)$ and the total constant dollar expenditure C_{X0} and determines the period-by-period constant dollar cash flows. This approach to modeling allows the modeler to simply specify the percentage or fraction of total expenditure that occurs in each time period.

Equations (11) and (12) define the cumulative design and construction costs in current dollars by incorporating the inflation rate θ, which would be expressed on a monthly basis as the basic time unit used is months:

$$C_D = \sum_{t=1}^{(1-A_{D)*}T_{Db}} c_{D_0}(t) * (1+\theta)^t \tag{11}$$

$$C_C = \sum_{t=(1-F)*T_D}^{(1-F)*T_D+(1-A_C)*T_C b} c_{C_0}(t) * (1+\theta)^t \tag{12}$$

IDC_P, as used in Equation (1), is the interest capitalized on private sector debt financing until the time the private sector starts servicing its debt, usually after receiving payment from the client for the portion of the capital cost it financed along with financing charges. Calculating the cumulative interest paid during the design and construction phases on private sector debt financing involves capitalizing interest earned, as the private sector debt servicing occurs after project completion. To calculate the IDC_P, the future value of private sector debt drawdowns, $d_p(t)$, is subtracted from the portion of current dollars capital cost which is financed by the private sector:

$$IDC_P = \left[\sum_{t=2}^{[(1-F)*T_D+T_C]+1} d_p(t) * (1+i_p)^{[[(1-F)*T_D+T_C]+1]-t} \right] - \sum_{t=2}^{[(1-F)*T_D+T_C]+1} d_p(t) \tag{13}$$

As with $d_M(t)$ in Equation (2), the private sector starts to make debt drawdowns at month 2. Therefore, the future value of private sector loan drawdowns is calculated from month 2, until month $[(1-F)*T_D+T_C]+1$, when the private sector pays for the cost incurred in month

$[(1-F)*T_D+T_C]$. IDC_P is only calculated under the DBF and DBFOM procurement modes when private sector debt financing is used, and covers both the design and construction phases.

It is worth noting that the value of i_P is different under the DBF and DBFOM procurement modes. Typically, i_P is lower under the DBF procurement mode than under the DBFOM mode. For the DBF procurement mode, the private sector uses short-term financing, with a debt maturity period following design and construction of usually less than 2 years, while for the DBFOM procurement mode, the private sector uses long-term financing which has a much longer maturity period, typically more than 25 years, which requires higher interest rates to compensate for the potential risks over an extended time period.

Besides the senior government contribution and private sector financing, a portion of the capital cost is financed by the municipal government which in turn incurs interest expenses during the design and construction periods. The cumulative interest paid during the design and construction phases on municipal debt financing does not include capitalized interest earned, as municipal debt servicing occurs on an ongoing basis. Thus,

$$IDC_M = \sum_{t=2}^{[(1-F)*T_D+T_C]+1} idc_M(t) \tag{14}$$

The value of the interest paid on municipal cumulative debt up until any given time t, $idc_M(t)$, is equal to the sum of the municipal government debt drawdowns, i.e., the sum of the $d_M(t)$ values, until the time t-1, multiplied by the municipal government interest rate, i_M. (Note that the sum of the $d_M(t)$ values does not include interest because interest costs are paid when incurred and on an ongoing basis.) No interest is paid until the third time period, because the municipal government

does not borrow funds to pay for expenditures incurred in time period one until the end of time period two.

$$idc_M(t) = \begin{cases} 0 & t \leq 2 \\ \left[\sum_{t=2}^{t-1} d_M(t)\right] * i_M & t \geq 3 \end{cases} \tag{15}$$

As the municipal government starts to raise debt drawdowns starting in month 2, $idc_M(t)$ for $t \leq 2$ is equal to zero.

To calculate $d_M(t)$ and $d_P(t)$ used in Equations (1) and (13), respectively, first the total senior government contribution available for use in each month inclusive of the cumulative amount of unused contribution monies plus interest earned on them including the most recent month, $tsc(t)$, is calculated to determine financing shortfalls which need to be covered by the municipal and private sector financing. To calculate $tsc(t)$:

$$tsc(t) = f(t) + p(t) + uisc(t-1) + ininc(t) \tag{16}$$

Where $f(t)$ and $p(t)$ are the magnitude of the federal and provincial contribution payments in each month, respectively, $uisc(t-1)$ is the value of senior government unissued contribution funds from previous months, and $ininc(t)$ is the interest income earned by the client on unissued senior government contribution funds during period *t*.

To calculate $f(t)$ and $p(t)$ which are set via the terms of the contribution agreement:

$$f(t) = [R_F * r_F(t)] * [r_{el} * TC] \tag{17}$$

$$p(t) = [R_{PR} * r_{PR}(t)] * \ [r_{el} \ * TC] \tag{18}$$

Where r_{el} is the eligibility ratio (assumed to be the same for the federal and provincial governments) as the federal and provincial governments only contribute to eligible costs of the project, R_F and R_{PR} are the ratio of the federal and provincial government contributions to the project, to TC, respectively, and $r_F(t)$ and $r_{PR}(t)$ are the fraction of R_F and R_{PR} contributed at each month running from time zero to $[(1-F) * T_D + T_C]$ +1. Note that:

$$\sum_{t=0}^{[(1-F)*T_D+T_C]+1} r_F = 1 \tag{19}$$

$$\sum_{t=0}^{[(1-F)*T_D+T_C]+1} r_{PR} = 1 \tag{20}$$

Contribution payments can be made as front-end loaded payments, at the beginning of the project, or as back-end loaded payments, at the end of construction phase, or they can be distributed as multiple milestone payments at the end of each milestone month. In order to make the model as general as possible, it is assumed that the federal and provincial government contribute $r_F(t)$ and $r_{PR}(t)$, respectively, as a fraction of R_F and R_{PR} at the end of each month. However, for the purpose of this thesis, in order to examine the two extremes of contribution timing, only front-end loaded (i.e., $r_F(t = 0)$ = 1) and back-end loaded payments (i.e., $r_F(\ t = [(1-F) * T_D + T_C]1\ )$ =

1) are considered in the case study application in Chapter 4. It is observed that $r_{PR}(t)$ is not necessarily the same as $r_F(t)$.

To calculate $uisc(t)$ in Equation (16):

$$uisc(t) = tsc(t) - isc(t) \tag{21}$$

where $uisc(t)$ is equal to the amount of money remaining from $tsc(t)$ after a certain amount of it is issued by the client to pay the contractor for expenses at the end of each month, $isc(t)$. To calculate $isc(t)$:

$$isc(t) = MIN(\,[c_D(t-1) + c_C(t-1)]\,, tsc(t)) \tag{22}$$

Due to the one-month lag between the timing of the design and construction expenditures and issuance of funding sources to the contractor for these expenditures, the value of $isc(t)$ is calculated based on the minimum value of either design and construction cost occurred in month $t-1, i.e.$, $[c_D(t-1) + c_C(t-1)]$, or $tsc(t)$.

The value of $ininc(t)$ in Equation (16) is calculated by multiplying the unissued senior government contribution from the most previous month by the short-term interest earning power of the municipal government, $i_{Mshorterm}$:

$$ininc(t) = uisc(t-1) * i_{Mshorterm} \tag{23}$$

As stated earlier, any financing shortfall (i.e., $[c_D(t-1) + c_C(t-1)] \ - isc(t)$) is covered by the client and private sector financing. The municipal government and private sector debt, and equity ratio (in percent form), are r_{d_M} , r_{d_P}, and r_{ep} , respectively. The borrowing level provided by the client, and the private debt and equity drawdowns in each month are calculated as follows:

$$d_M(t) = r_{d_M} * [\ [c_D(t-1) + c_C(t-1)] \ - isc(t)] \tag{24}$$

$$d_P(t) = r_{d_P} * [\ [c_D(t-1) + c_C(t-1)] \ - isc(t)] \tag{25}$$

$$e_P(t) = r_{ep} * [\ [c_D(t-1) + c_C(t-1)] \ - isc(t)] \tag{26}$$

From the perspective of the federal and provincial governments, the contribution payments incur interest expenses during the design and construction periods as the governments finance their contributions through borrowing. Similar to the municipal cumulative interest expense during the design and construction phases, calculated in Equation (15), the cumulative interest expense on federal and provincial debt financing, IDC_F and IDC_{PR}, respectively, are determined as follows:

$$IDC_F = \sum_{t=1}^{(1-F)*T_D+T_C} idc_F(t) \tag{27}$$

$$IDC_{PR} = \sum_{t=1}^{(1-F)*T_D+T_C} idc_{PR}(t) \tag{28}$$

in which $idc_F(t)$ and $idc_{PR}(t)$ are equal to $f(t)$ and $p(t)$ multiplied by the federal and provincial government interest rate, i_F and i_{PR}, respectively:

$$idc_F(t) = \begin{cases} 0 & t = 0 \\ \left[\sum_{t=0}^{t-1} f(t)\right] * i_F & t > 0 \end{cases} \tag{29}$$

$$idc_{PR}(t) = \begin{cases} 0 & t = 0 \\ \left[\sum_{t=0}^{t-1} p(t)\right] * i_{PR} & t > 0 \end{cases} \tag{30}$$

3.3 Numerical Example

A small example is presented in this section to illustrate the application of the various relationships developed in Section 3.2 and to test their validity by an independent approach. The example is purposely small in scale (project cost and time frame) to keep it simple while at the same time demonstrating several of the relationships developed. The context is that of a DBF procurement mode for a municipal client, with both the federal and provincial governments making contributions. The following assumptions are made for the purpose of this example:

- The capital costs are expressed directly in current dollars to minimize the complexity of the model.
- The provincial government makes a front-end loaded contribution payment while the federal government provides a back-end loaded contribution payment.
- Except for any front-end loaded contribution, discrete end of period cash flows are assumed.

- Client progress payments and drawdown of DBF contractor loan payments are made with a one-month lag.
- It assumed there is no acceleration or fast-tracking during the design and construction phase.
- Federal and provincial contribution payments are made directly to the municipality. There is no contractual relationship between the federal or provincial governments with the DBF contractor.
- It is assumed that the client requires that the DBF contractor borrows from their lending agency on a pro rata basis (i.e., a pre-specified ratio of each progress payment is sourced from contractor financing) from the start of construction (considering the lag time).
- The balance of funding sources comes from the municipality and includes direct borrowing plus any interest earned on early contribution payment(s).
- No contractor equity financing is required.
- The construction expenditure profile from the perspective of the contractor is shown in Figure 3.4. Flows in each layer have a magnitude of $2 million (base flow is $2 million, then moves up to 4 million, then peaks at $6 million – treated as separate layers for purposes of independent computation).

The input date used in this example are summarized in Table 3.7:

Parameter	Unit	Value
$C_C + C_D$	$ Current million	42
$T_C + T_D$	Month	9
R_F	%	33.3% (fraction of eligible costs)
R_{PR}	%	33.3% (fraction of eligible costs)
r_P	%	25.0%
r_{el}	%	85.0%
i_f	%	[9]0.3274% (Annual 3%)
i_{PR}	%	0.3875% (Annual 4.75%)
i_M	%	0.4472% (Annual 5.5%)
i_P	%	0.5645% (Annual 7%)
$i_{Mshorterm}$	%	0.1324% (Annual 1.6%)
$r_F(10)$	Fraction	1
$r_P(0)$	Fraction	1

Table 3-7 Numerical example input data

The goal of this example is to calculate IDC_P and total municipal financing by two different solving approaches, one presented in Section 3.3.1 and the other by the equations proposed in this thesis in Section 3.2 to demonstrate that both solving approaches yield the same unique solution. The goal is to test the validity of the model presented in Section 3.2 by an independent approach.

[9] Conversion from effective annual rate to effective monthly rate and vice versa via $i = \left(1 + \frac{r}{m}\right)^m - 1 \; in \; which$ $i = effective\ annual\ rate, r = nominal\ annual\ rate,$ and $\frac{r}{m} = monthly\ effective\ rate.$
Knowing *i* and *m*, (equal to 12) have solved for *r*/*m* (monthly effective and nominal rate) as follows:

$$\frac{r}{m} = \left[\sqrt[m]{(1+i)} - 1\right]$$

3.3.1 An Independent Validation Approach

Define the contributions from the federal (*f*) and provincial (*p*) governments as:

$$f = R_F * r_{el} * TC$$

And,

$$p = R_{PR} * r_{el} * TC$$

Also, recall:

$$TC = C_D + C_C + IDC_P$$

Federal and Provincial Contributions

Contributions of the federal and provincial governments are:

$$Federal(f)\ \&\ Provincial(p)\ contribution\ each = R_F * r_{el} * TC$$

$$= R_F * r_{el} * (C_D + C_C + IDC_P)\ (note: R_{PR} = R_F)$$

$$f\ \&\ p\ each = 0.333 * 0.85 * (42 + IDC_P) = 0.2830 * (42 + IDC_P)$$

In terms of timing of contributions, federal contribution, $f(t)$ is equal to zero for all t except $f(10) = 1$ (back-end loaded). Provincial contribution, $p(t)$ is equal to zero for all *t* except $p(0) = 1$ (front-end loaded).

Contract with DBF Contractor

Financing from the contractor is equal to $10.5 million (0.25 * 42). In addition to monthly progress payments from the client, the client provides a lump sum payment at $t = 10$ to cover contractor financing (principal + interest).

Municipal Contribution

The balance of funding comes from the municipality and includes direct municipal borrowing plus any early senior government contributions plus interest earned on early contribution payment(s).

Thus, the following relationship results:

$$TC = C_D + C_C + IDC_P = f + p + contractor + municipality$$
$$= 2 * 0.2830 * (42 + IDC_P) + 0.25 * 42 + municipality$$

The ultimate source of all payments to the DBF contractor is simply the senior government contributions (inclusive of any interest earned on front-end contributions) and the municipality. Thus, the interim contractor financing helps the municipality defer some of its payment until completion of the project.

To calculate IDC_P , the future worth of contractor financing flows to time 10, with i_P = 0.005645 is calculated as:

$$IDC_P = 2 * 0.25 * \left[\left(F/A, i_{P,}9\right) + \left(F/A, i_{P,}7\right) * (F/P, i_P, 1) + \left(F/A, i_{P,}5\right) * (F/P, i_P, 2)\right] - 10.5$$
$$= 0.5 * [9.2509 + 7.1196 * 1.0056 + 5.0567 * 1.0113] - 10.5 = 10.7399 - 10.5$$
$$= \$0.2399 \text{ million}$$

Where the factors for the future value of a single payment and the future value of a uniform series are:

$$(F/A, i, N) = \frac{(1+i)^N - 1}{i} \; and \; (F/P, i, N) = (1+i)^N$$

Thus:

$$TC = C_D + C_C + IDC_P = f + p + contractor\ financing + municipal\ financing$$

$$= 42 + 0.2399$$

$$= 2 * 0.2830 * (42 + 0.2399) + 0.25 * 42 + municipal\ financing$$

But timing of the senior government contribution is important to the sourcing of municipal progress payments. The municipal progress payments during design and construction phases are sourced from the provincial front-end contribution plus any interest earned on unused contribution monies. Table 3.8 shows the project cash flow for this example including the municipal government's monthly progress payments. (Note: values have not been rounded in this table.) In month 10, the municipal government provides a lump sum payment to cover contractor financing (principal + interest) along with progress payment to pay the cost in month 9. To calculate the total municipal financing, first the contribution from the federal government is calculated:

$$0.2830 * 42.2399 = \$11.956 \text{ million}$$

The discharge of the contractor loan including interest is:

$$10.5 + 0.2399 = \$\ 10.7399 \text{ million;}$$

The difference between the federal government contribution and discharge is:

$$= 11.956 - 10.7399 = \$1.2116 \text{ million}$$

The municipal government uses the $1.2116 for part of the last progress payment. Therefore, based on calculations above and Table 3-8 the total municipal financing is:

$$= 1.4845 + (3 * 4.5) + 3 + 1.5 - 1.2116 = \$\ 18.2684\ million$$

Time, t	Construction expenditure function, c(t)	Contractor financing	Municipal payments (1 mth lag)	Source of municipal payments	Provincial contribution	Federal contribution	Contribution funds + interest available	Cumulative Municipal borrowing	Municipal Interest payment (0.0044720)
0	0.00	0.00	0.00		***11.956***	0.00	11.95600	0.00	0.00
1	2.00	0.00	0.00		0.00	0.00	11.97183	0.00	0.00
2	4.00	0.50	1.50	pcontrib	0.00	0.00	10.48768	0.00	0.00
3	6.00	1.00	3.00	pcontrib	0.00	0.00	7.50157	0.00	0.00
4	6.00	1.50	4.50	pcontrib	0.00	0.00	3.01150	0.00	0.00
5	6.00	1.50	4.50	partpcont	0.00	0.00	-1.48451	1.48451	0.00
6	6.00	1.50	4.50	munifinance	0.00	0.00	0.00000	5.98451	0.006639
7	6.00	1.50	4.50	munifinance	0.00	0.00	0.00000	10.48451	0.026763
8	4.00	1.50	4.50	munifinance	0.00	0.00	0.00000	14.98451	0.046887
9	2.00	1.00	3.00	munifinance	0.00	0.00	0.00000	17.98451	0.067011
10		0.50	1.50	munifin+fedc		***1.2161***	***1.2161***	18.26841	0.080427
10			***10.7399***	fcontrib	0.00	***10.73990***	***10.73990***		
	42.00	**10.50**	**42.2399**	**0.0000**		**11.95600**			**0.227726**
	For 4.5 payment, 3.015485 = p contrib+int., 1.48451 from muni								
	some comes from feds - i.e. 11.956 - 10.7399 = 1.2161								
	Municipal payments financed = 1.48451 +13.5+3.0+1.5-1.2161 = 18.26841								

Table 3-8 Numerical example cash flow using the independent validation approach

3.3.2 Cash Flow Modeling Approach

From Equation (2), the total capital cost is:

$$TC = C_D + C_C + IDC_P$$

$$= 42 + IDC_P$$

From Equation (17) the federal back-end load contribution payment is:

$$f(10) = [R_F * r_F(10)] * [r_{el} * TC]$$

$$= 0.85 * 0.333 * (42 + IDC_P)$$

From Equation (18) the provincial front-end load contribution payment is:

$$p(0) = [R_{PR} * r_{PR}(0)] * [r_{el} * TC]$$

$$= 0.85 * 0.333 * (42 + IDC_P)$$

In order to calculate IDC_P, first the private sector's loan drawdown in each month is calculated. The private sector is required to finance the project from the start of project (considering a one-month lag) on a pro-rata basis disregarding any available senior government contributions which are managed by the client. Therefore, the calculation of $d_p(t)$ in Equation (25) is changed to:

$$d_p(t) = 0.25 * \big((c_D + c_C)(t-1)\big)$$

For example, for $t = 2$:

$$d_p(2) = 0.25 * ((c_D + c_C)(1))$$

$$= 0.25 * 2 = 0.5$$

The calculation of $d_p(t)$ for other months is provided in Table 3.9.

Timeline	0	1	2	3	4	5	6	7	8	9	10	SUM
$C_D + C_C$	0.0000	2.0000	4.0000	6.0000	6.0000	6.0000	6.0000	6.0000	4.0000	2.0000	0.0000	**42.0000**
IDC_P			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2399	**0.2399**
Repayment of contractor laon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	10.5000	**10.5000**
f(t)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	11.9560	
p(t)	11.9560	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
ininc(t)	0.0000	0.0158	0.0159	0.0139	0.0098	0.0039	0.0000	0.0000	0.0000	0.0000	0.0000	
isc(t)	0.0000	0.0000	1.5000	3.0000	4.5000	3.0100	0.0000	0.0000	0.0000	0.0000	0.0000	
uisc(t)	11.9560	11.9718	10.4877	7.5016	3.0113	0.0000	0.0000	0.0000	0.0000	0.0000	11.9560	
tsc(t)	11.9560	11.9718	11.9877	10.5016	7.5113	3.0100	0.0000	0.0000	0.0000	0.0000	11.9560	
d_M	0.0000	0.0000	0.0000	0.0000	0.0000	1.4900	4.5000	4.5000	4.5000	3.0000	0.2839	**18.2684**
D_P	0.0000	0.0000	0.5000	1.0000	1.5000	1.5000	1.5000	1.5000	1.5000	1.0000	0.5000	**10.5000**

Table 3-9 Numerical example cash flow using the cash flow modeling approach

From Equation (13), for calculation of IDC_P:

$$IDC_P = \left[\sum_{t=2}^{T_D+T_C+1} d_p(t) * \left(1+i_p\right)^{[T_D+T_C]+1]-t}\right] - \sum_{t=2}^{[T_D+T_C]+1} d_p(t) = [0.5 * (1+0.0056)^8 + 1$$

$$* (1+0.005645)^7 + 1.5 * (1+0.005645)^6 + 1.5 * (1+0.005645)^5 + 1.5$$

$$* (1+0.005645)^4 + 1.5 * (1+0.005645)^3 + 1.5 * (1+0.005645)^2 + 1$$

$$* (1+0.005645)^1 + 0.5] - 10.5 = \$0.2399\ million$$

This value of IDC_P is equivalent to that found using the independent validation approach above. Therefore $f(10)$ and $p(0)$ are:

$$f(10) = p(0) = 0.85 * 0.333 * (42 + 0.2399) = \$11.956 \text{ million}$$

In general, in calculating municipal financing with Equation (24), the assumption is that funding shortfalls (after consideration of the use of any available senior government contribution monies) are covered by both municipal and private sector financing, However in this simple example, the private sector borrows money from the beginning of the project (i.e., after a one-month lag time) and the municipal government covers a shortfall after consideration of the use of both the senior government contribution, and the private sector financing. Therefore, to calculate municipal financing in each month, Equation (24) is modified to:

$$d_M(t) = ((c_D + c_C)(t-1)) - (isc(t) - d_p(t))$$

For example, for $t = 2$:

$$d_M(2) = ((c_D + c_C)(1)) - \left(isc(2) + d_p(2)\right)$$

$$= 2 - (isc(2) + 0.5)$$

The amount of money that the client issues from the senior government contribution in each month, $isc(t)$, is also changed as follows to consider the contractor financing in each month:

$$isc(t) = ((c_D + c_C)(t-1)) - d_P(t)$$

For $t = 2$:

$$isc(2) = (((c_D + c_C)(1)) - d_P(2)$$

$$= \ 2 - 0.5 = \$1.5 \text{ million}$$

$$d_M(2) = \ 2 - (isc(2) - 0.5)$$

$$= 2 - (1.5 + 2) = \$0 \text{ million}$$

However, the above relationship is used only if the total senior government contribution available in each month is equal to or greater than the issued senior government contribution in that month, i.e., $tsc(t) \geq isc(t)$; otherwise, $isc(t)$=0, because the total amount of senior government contribution is used up. In this case, the municipal government starts to borrow money to fund any shortfalls. From Equation (16), $tsc(t)$ is:

$$tsc(t) = f(t) + p(t) + uisc(t-1) + ininc(t)$$

For $t = 2$:

$$tsc(2) = f(2) + p(2) + uisc(1) + ininc(2)$$

$$= 0 + 0 + uisc(1) + ininc(2)$$

Also, from Equations (23) and (21):

$$ininc(t) = uisc(t-1) * i_{Mshorterm}$$

$$uisc(t) = tsc(t) - isc(t)$$

For $t = 2$:

$$ininc(2) = uisc(1) * i_{Mshorterm}$$

$$= uisc(1) * 0.001324$$

For $t = 1$:

$$uisc(1) = tsc(1) - isc(1)$$

Because of the one-month lag, the client starts issuing payment to the contactor from senior government contribution money from month 2, then: $isc(1) = \$0$ million

And for $t = 1$:

$$tsc(1) = f(1) + p(1) + uisc(0) + ininc(1)$$

$$= 0 + 0 + uisc(0) + ininc(1)$$

For $t = 0$:

$$uisc(0) = tsc(0) - isc(0)$$

$$= 11.956 - 0 = \$11.956 \text{ million}$$

And for $t = 1$:

$$ininc(1) = uisc(0) * i_{Mshorterm}$$

$$= 11.956 * 0.001324 = \$0.0158 \text{ million}$$

Therefore,

$$tsc(1) = 11.956 + 0.0158 = \$11.9718 \text{ million}$$

$$ininc(2) = 11.9718 * 0.001324 = \$0.0159 \text{ million}$$

$$tsc(2) = 11.9718 + 0.0159 = \$11.9877 \text{ million}$$

This shows $tsc(2) \geq isc(2)$ ($11.9877 million ≥ $1.5 million), therefore, the equation $isc(t) = (((C_D + C_C)(t-1)) - d_P(t)$ can be used for calculation of $isc(t)$. The calculation of all variables used in the above equations for the other months are provided in Table 3-9.

In month 10, the municipal government provides a lump sum payment to cover contractor financing (principal + interest =10.5+ 0.2399) along with progress payment to pay the cost in month 9. From the Table 3-9, the total municipal government contribution is equal to $18.2684 million.

Figures 3-4 to 3-7 demonstrate the example cash flow diagrams to represent the flow of money in each month from different project participants viewpoint, including, the municipal government, private sector, federal and provincial governments.

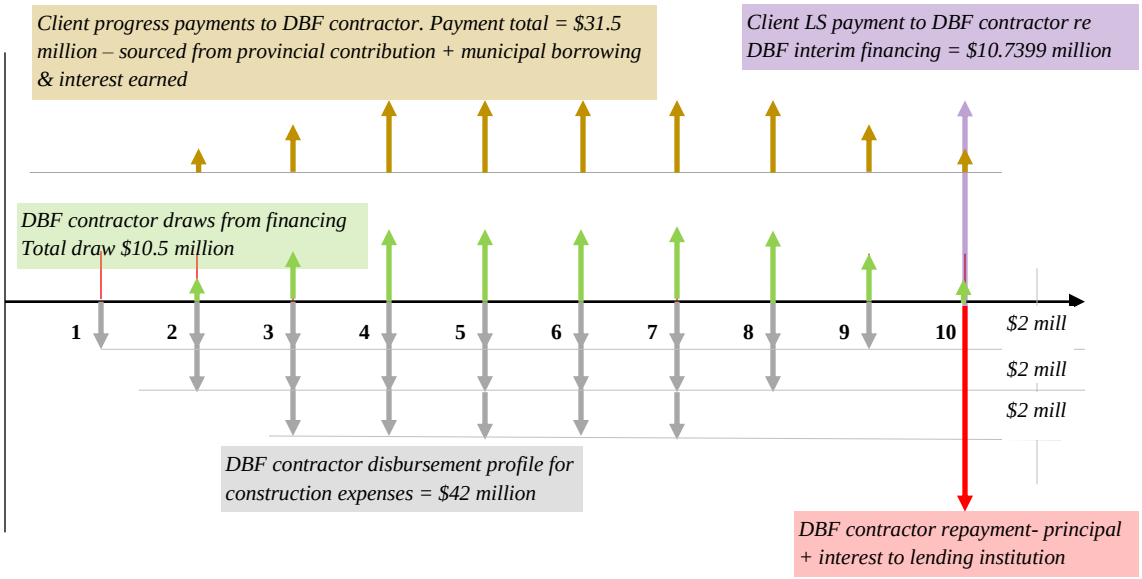

Figure 3-4 Cash flow diagram from the perspective of the DBF contractor-numerical example

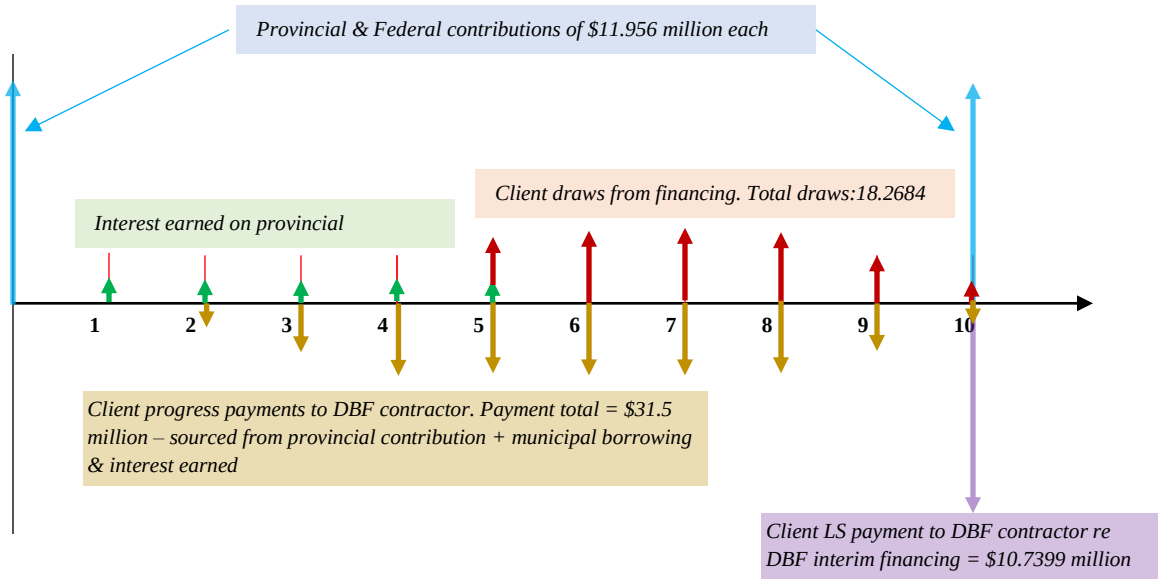

Figure 3-5 Cash flow diagram from the perspective of the client-numerical example

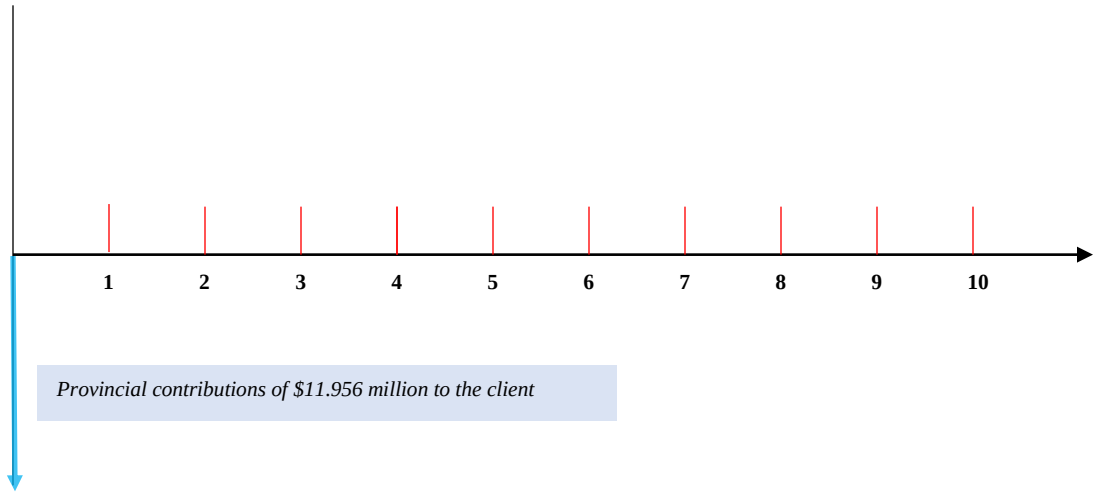

Figure 3-6 Cash flow diagram from the perspective of the provincial government-numerical example

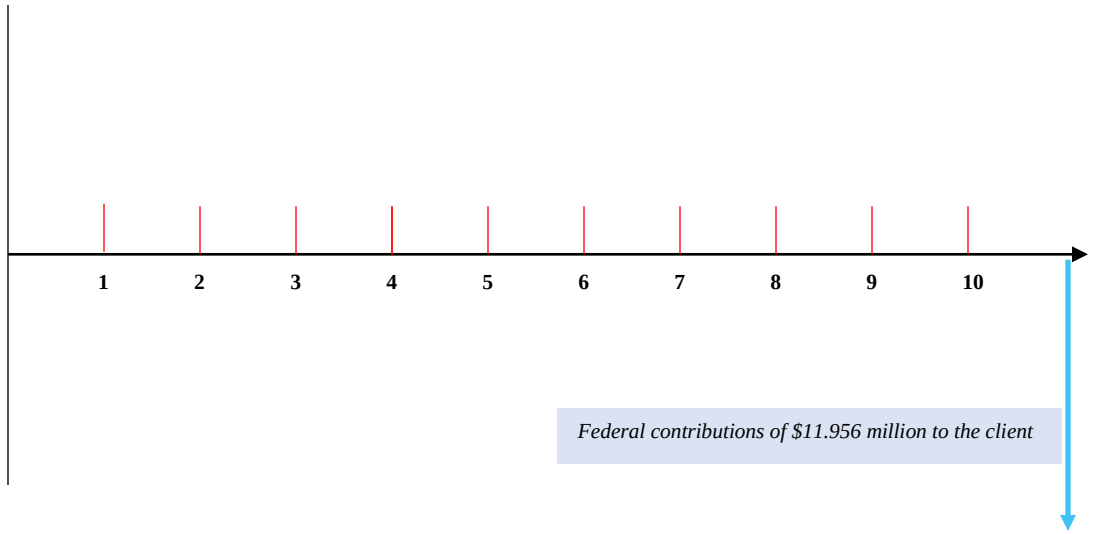

Figure 3-7 Cash flow diagram from the perspective of the federal government-numerical example

The comparison between using the independent validation and cash flow modeling approach shows that the value of IDC_P in both approaches is the same, as well as, the total municipal government contribution. This result demonstrates that the model presented in Section 3.2 is valid. Moreover, a comparison between these two approaches shows that the model proposed in Section 3.2 is more general and flexible. For example, one can easily add milestone payments from senior government contributions and keep track of any interest earned on them to calculate the total senior government contribution in each month. Also, the model can be tailored to reflect different assumptions. For example, the model is based on the assumption that the client allows the private sector to defer borrowing until the total senior government contribution is used up, while, in the example in Section 3.3, it is assumed that the client wants the private sector commitment from the start of the construction (considering the one-month lag) to take advantage of oversight from the DBF's

financing agency. Therefore, the corresponding equations were modified to reflect these problem assumptions.

3.4 Cash Flow Diagrams for Procurement Modes

Figures 3-8 to 3-20 show example cash flow diagrams from the perspective of each project proponent, i.e., the client, the senior levels of government, and the private sector contractor, developed based on the model presented herein under the DBB, BDF and DBFOM procurement modes. The intent is to represent the flow of money in each month and show a generalization of the simple example presented in the previous section, but for all three procurement modes.

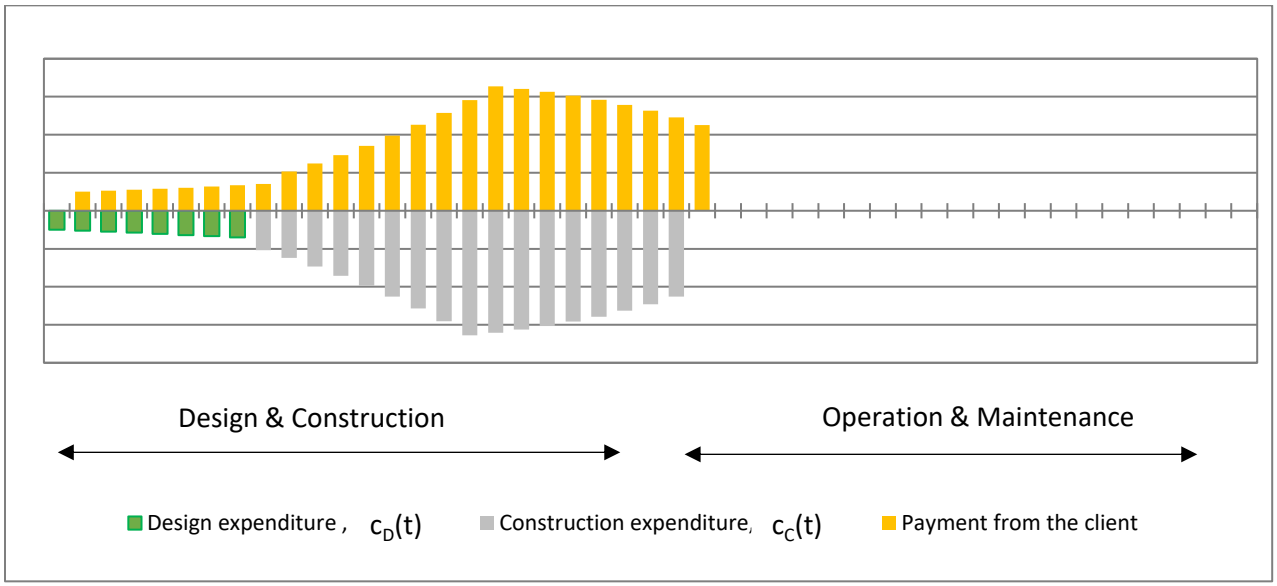

Figure 3-8 Cash flow diagram from the perspective of the design and construction contractor under the DBB procurement mode

The design firm and the construction contractor receive progress payments from the client to pay for their expenses. However, the progress payments lag by one month behind the corresponding expenditures. Since, under the DBB procurement mode, the responsibility of financing the capital

cost is that of the client, how the project is financed by the client and the timing of senior level of government contributions does not affect the contractor cash flow diagram.

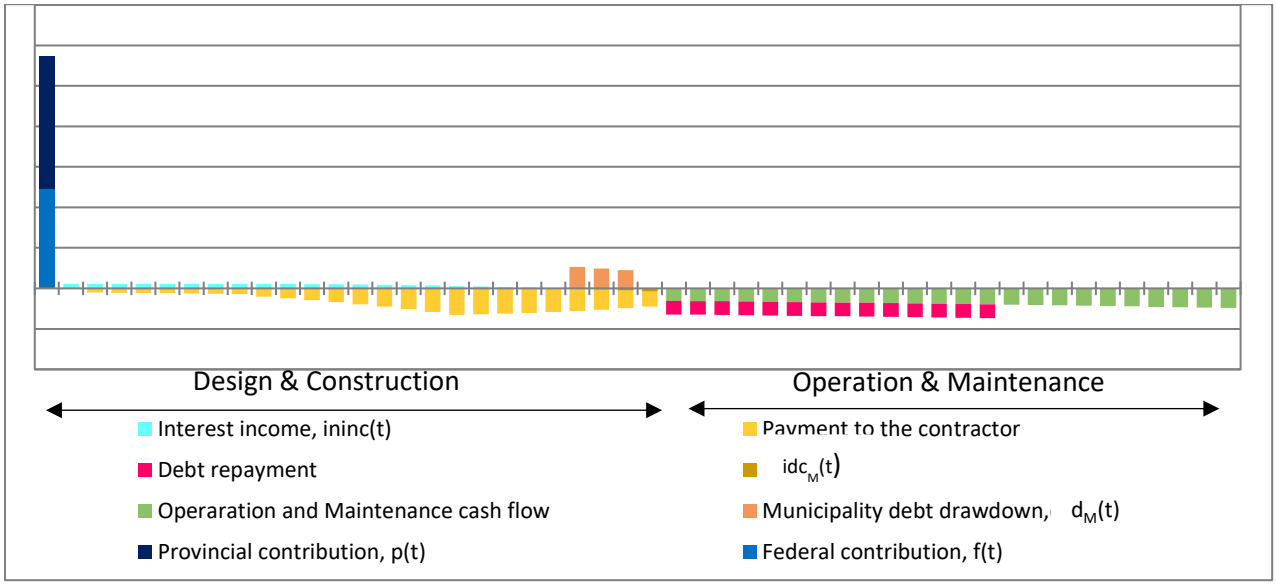

Figure 3-9 Cash flow diagram from the perspective of the client with front-end loaded senior government contribution payments under the DBB procurement mode

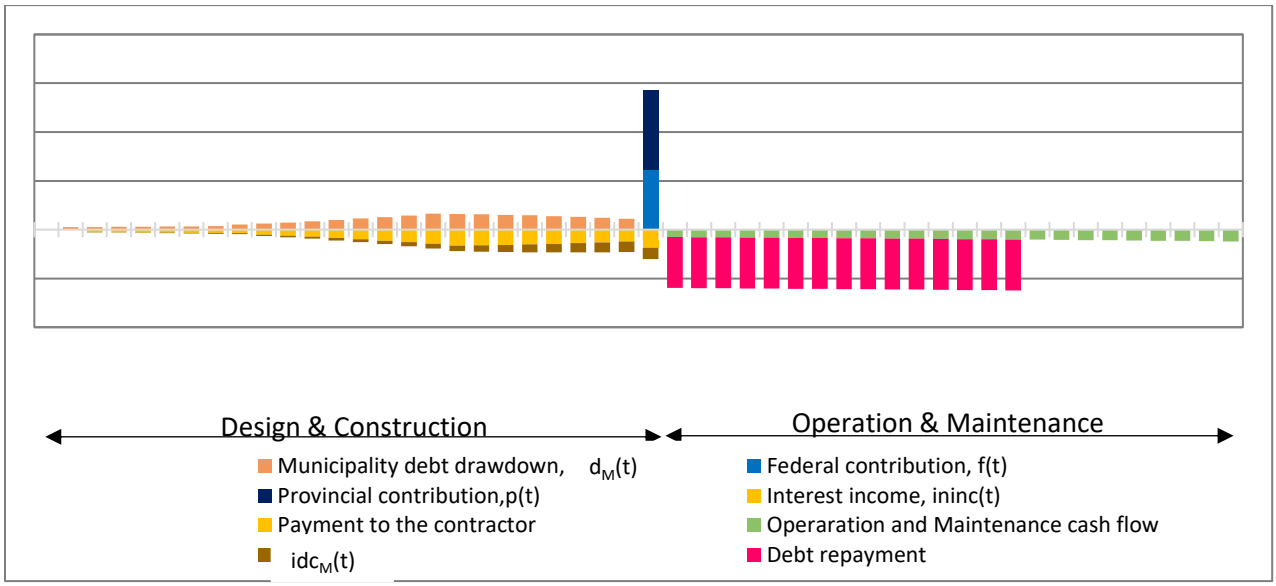

Figure 3-10 Cash flow diagram from the perspective of the client with back-end loaded senior government contribution payments under the DBB procurement mode

Figures 3-9 and 3-10 show the cash flow diagrams from the perspective of the municipal government with front-end loaded and back-end loaded contribution payments, respectively, from the senior levels of government. As discussed above, in the case of a front-end contribution, the funds can be invested in an interest-earning account until there is a need to use them. The client finances the design and construction costs incurred by the contractor through the federal and provincial contributions and the interest income earned on them. Any financing deficiencies are covered by the client's other funding sources. As shown in Figures 3-9, in the case of a front-end loaded payment, the municipal government can defer debt financing to the later months of the construction period which reduces their cost of borrowing. However, under a back-end loaded payment mechanism, since the federal and provincial contribution funding is not available until the end of project completion, the municipal government finances the total costs of the project during the design and construction phase. The back-end loaded payment from the federal and provincial government can be used to repay a portion of the capital costs expended by the client.

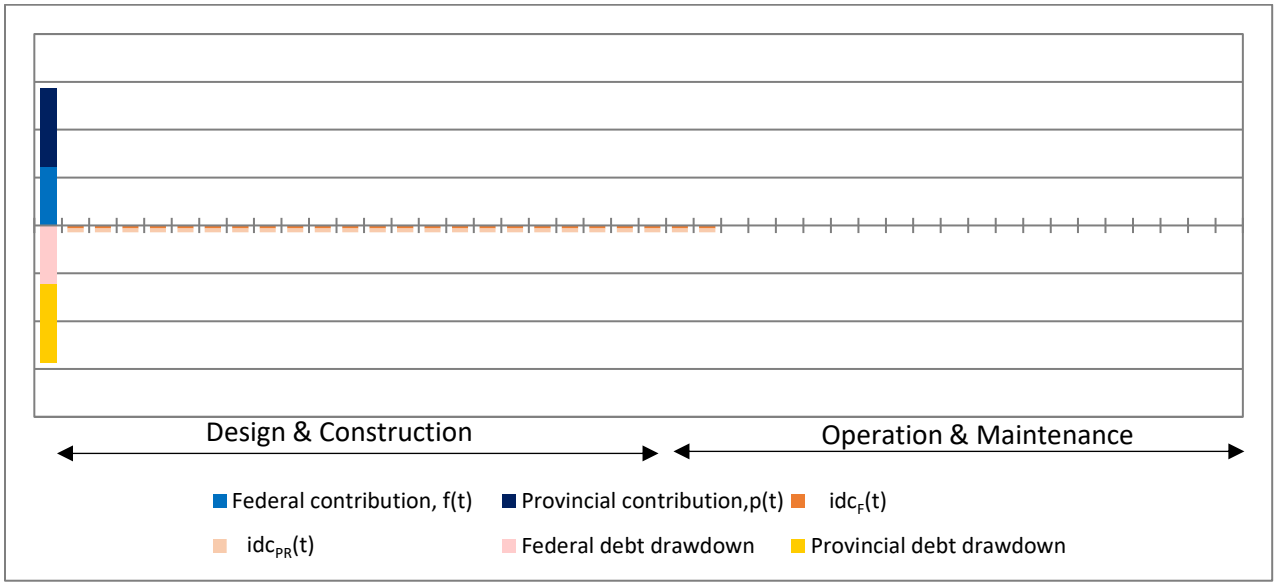

Figure 3-11 Cash flow diagram from the perspective of the senior government with front-end-loaded contribution payments under the DBB, DBF, and DBFOM procurement modes

Figure 3-11 shows the senior government cash flow diagrams with a front-end loaded contribution payment which incurs interest expenses during the design and construction periods as government finances the contributions through borrowing. In the case of a back-end loaded payment, the interest expenses incurred by the senior government occur after the construction phase at times beyond the scope of this study.

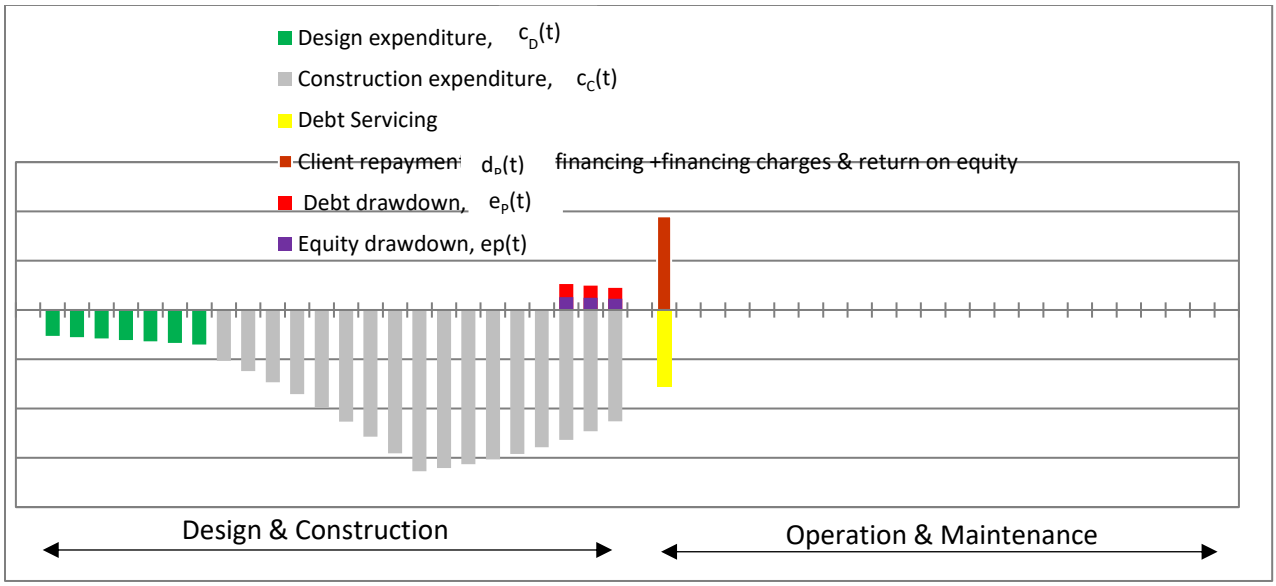

Figure 3-12 Cash flow diagram from the perspective of the contractor with front-end-loaded senior government contribution payments under the DBF procurement mode

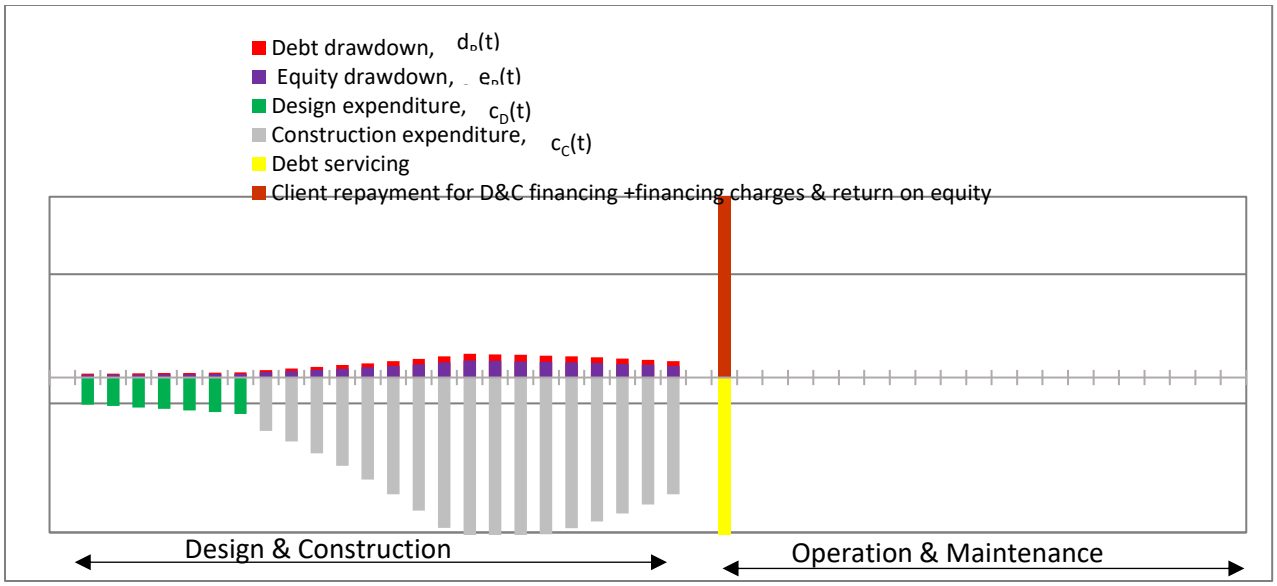

Figure 3-13 Cash flow diagram from the perspective of the contractor with back-end loaded senior contribution payments under the DBF procurement mode

Figures 3-12 and 3-13 are the cash flow diagrams from the view point of the contractor, with front-end and back-end loaded federal contribution payments under the DBF procurement mode, similar to what was shown for the simple example in Section 3.3. The capital cost is financed through the federal and provincial contributions and the interest revenue. Any financing deficiency is covered by municipal debt financing and private sector debt and possibly equity financing. Typically, the private sector uses short term debt financing which means it is repaid in a relatively short time period after project completion. The client pays back the contractor for the portion of total cost financed by private equity and debt along with financing costs and return on equity.

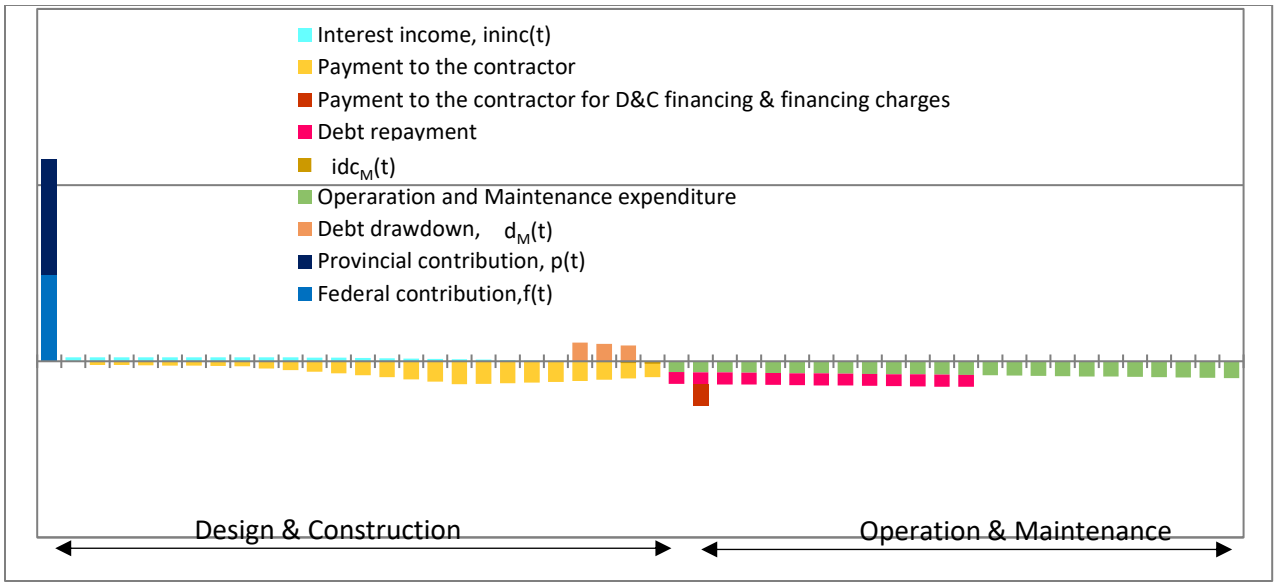

Figure 3-14 Cash flow diagram from the perspective of the client with front-end loaded senior government contribution payments under the DBF procurement mode

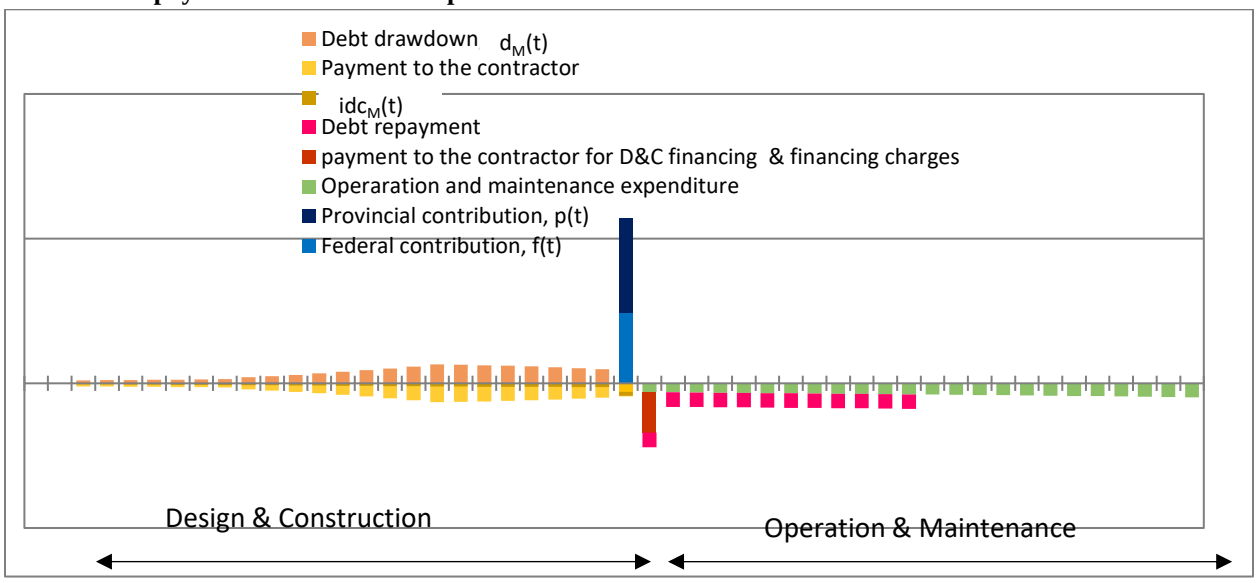

Figure 3-15 Cash flow diagram from the perspective of the client with back-end loaded senior government contribution payments under the DBF procurement mode

Illustrated in Figures 3-14 to 3-15 are the client cash flow diagrams with a front-end and back end loaded contribution payment, respectively. Municipal debt is another source for financing the project capital cost.

Similar to the DBB procurement mode, in DBF, the operation and maintenance costs are the responsibility of the client which should be financed through municipal funding sources.

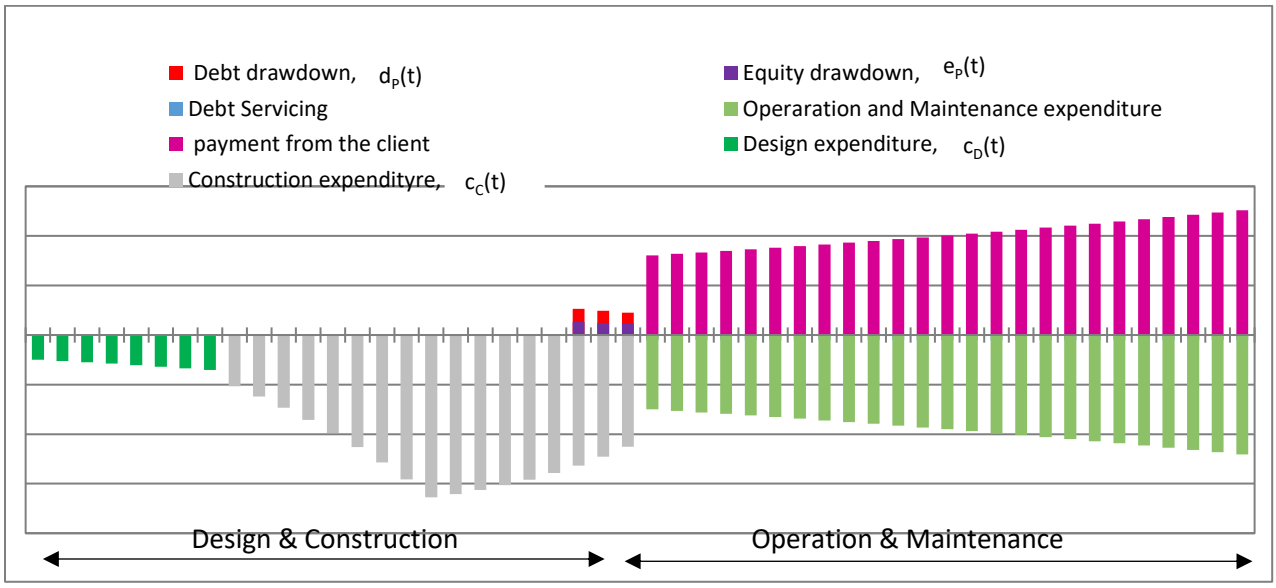

Figure 3-16 Cash flow diagram from the perspective of the contractor with front-end loaded senior government contribution payments under the DBFOM procurement mode

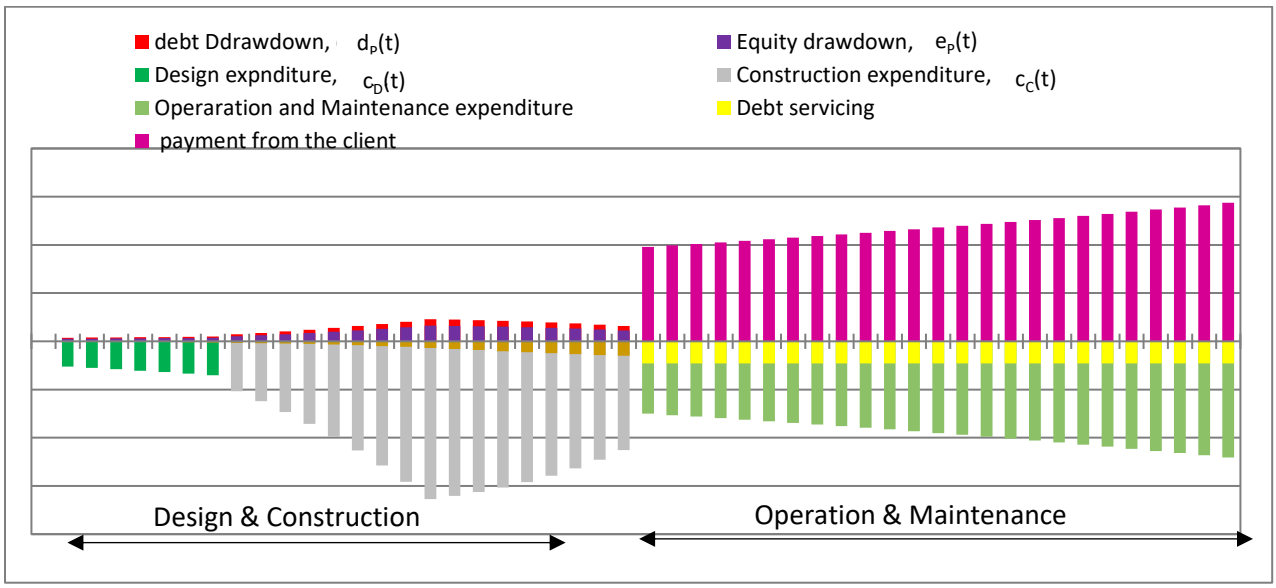

Figure 3-17 Cash flow diagram from the perspective of the contractor with back-end loaded senior government contribution payments under the DBFOM procurement mode

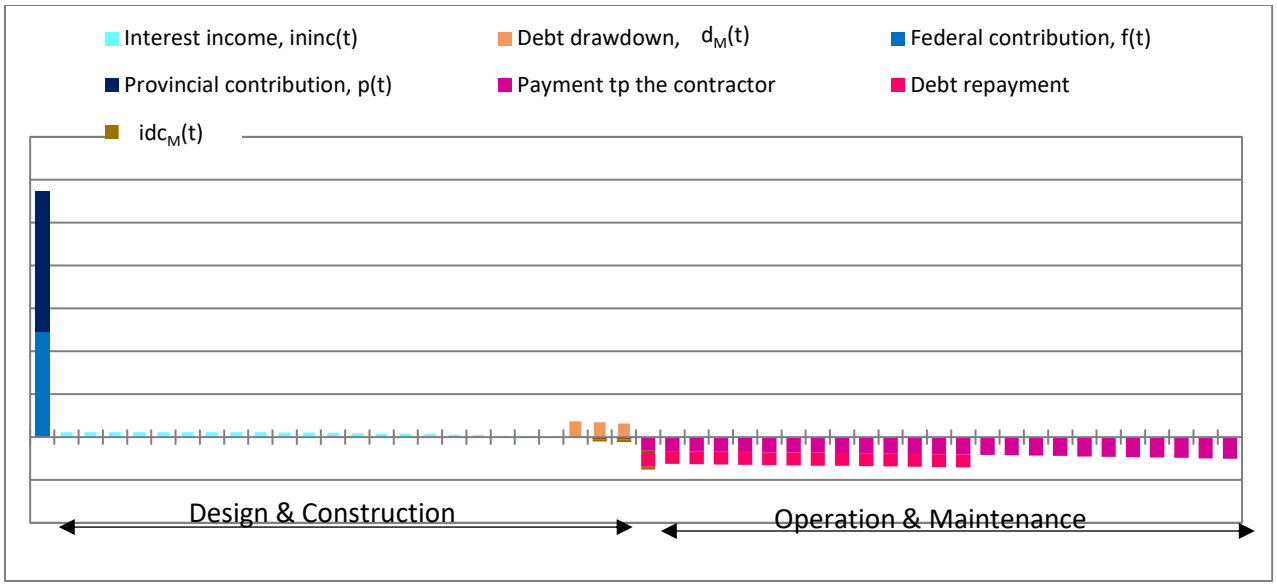

Figure 3-18 Cash flow diagram from the perspective of the client with front-end loaded senior government contribution payments under DBFOM procurement mode

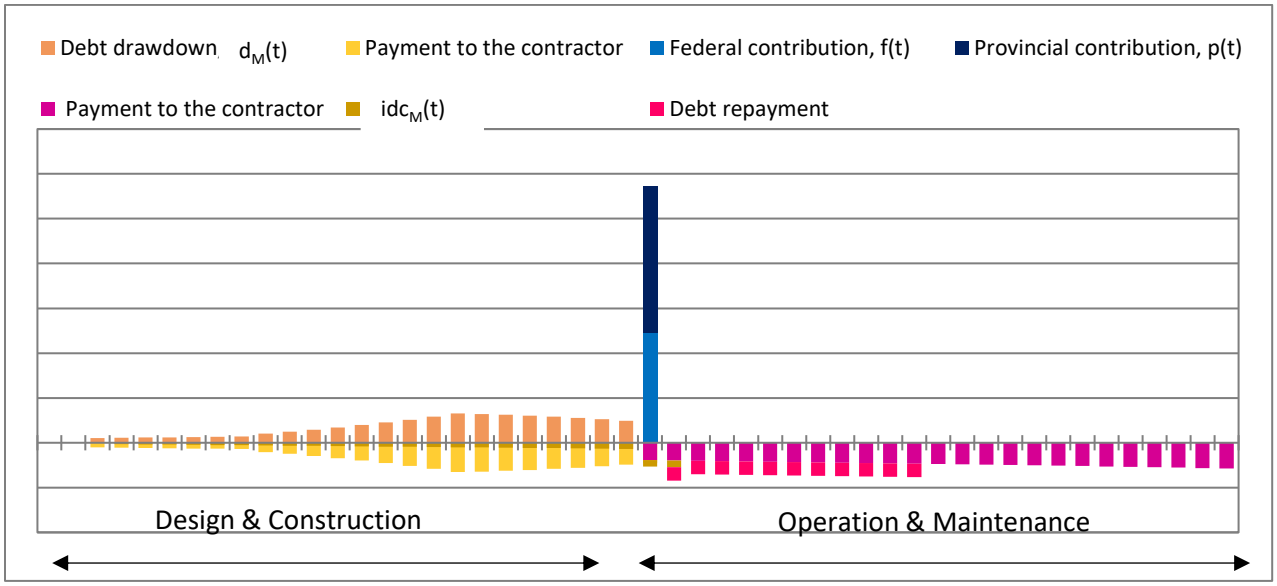

Figure 3-19 Cash flow diagram from the perspective of the client with back-end loaded senior government contribution payments under DBFOM procurement mode

Figures 3-16 to 3-19 are cash flow diagrams of the client and the concessionaire, with a front-end loaded and a back-end loaded senior government contribution payment under DBFOM procurement mode.

In the next chapter, in order to show model consistency, a sensitivity analysis is conducted. Some of the parameters of the model, including the inflation rate, cumulative construction cost in constant dollars, construction period, and interest rate of municipal government, θ, C_{C0}, T_C, and i_M respectively, are varied by +/- 20% of their base values to observe the changes in a given metric.

Chapter 4: Case Study: Lions Gate Secondary Wastewater Treatment Plant

In this chapter a case study of the Lions Gate Secondary Wastewater Treatment Plant is used to examine the model developed in Chapter 3. Project background is provided followed by model data parameters. In Section 4.4 an analysis is conducted to explore the sensitivity of the performance metrics to changes in the contribution agreement parameters. The calculation of variable values, including the performance metrics in the model and the sensitivity analysis is carried out using MATLAB.

4.1 Project background

The existing Lions Gate Wastewater Treatment Plant was commissioned in 1961 to provide primary treatment for residents of the North Shore, specifically the West Vancouver, the City of North Vancouver and the District of North Vancouver. Based on new strategies for Management of Municipal Wastewater Effluent endorsed in 2009 by federal government, all primary treatment plants are required to be upgraded to secondary treatment. To comply with federal regulations, the existing Lions Gate Wastewater Treatment Plant is being replaced by new facilities to provide secondary treatment to approximately 200,000 residents on the North Shore of Burrard inlet. The plant will be fully commissioned and operational by the end of 2020. Figure 4-1 shows the project timeline:

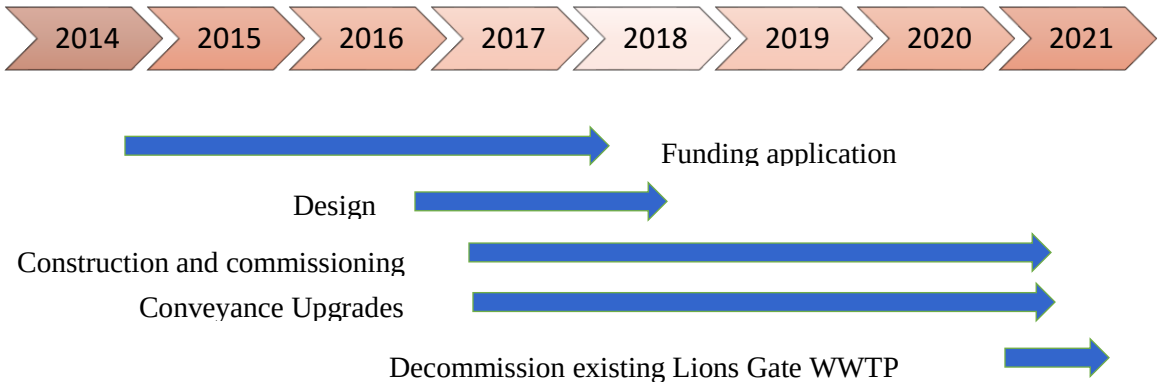

Figure 4-1 Lions Gate Secondary Wastewater Treatment Plant timeline

The project delivery mode is DBF and the total estimated project cost, including the conveyance and decommissioning, is $700 million dollar. The federal government contributed $212.3 million toward the project cost under the provincial-Territorial Infrastructure Component of New Building Canada Fund. The province of British Columbia also contributed $193 million toward eligible costs.

4.2 Model Inputs

The model assumptions are those listed in Chapter 3. Model inputs are divided to two kinds of data: investment parameters which include financial data, macroeconomic data, and project data, provided in Table 4-1 and 4-2, and senior government contribution agreement parameters, provided in Table 4-3 and discussed in Section 4.2.1. The values of the parameters are based on recommendations in KPMG (2014) or expert opinion (personal correspondence with A. Russell, 2019). Although the amounts of federal and provincial contribution in this project are different, they are assumed to be equal herein for simplicity. While it is not realistic to assume that design and construction costs and delivery times are the same across all procurement modes, in order to

explore the sole effect of contribution agreement terms on the performance metrics, it is assumed that there are no differences between procurement modes with respect to these factors.

Name	Symbol	Unit or reported as	DBB	DBF	DBFOM	Source
Degree of acceleration during the construction phase	A_C	%	0%	0%	0%	-
Degree of acceleration during the design phase	A_D	%	0%	0%	0%	-
degree of overlap between design and construction phases	F	%	0%	0%	0%	-
Constant dollar cumulative construction cost	C_{C0}	$	$475	$475	$475	KPMG
Constant dollar cumulative design cost	C_{D0}	$	$75	$75	$75	KPMG
Expenditure ratio during construction phase at time t	$exp_{C0}(t)$	%	Table 4-2	Table 4-2	Table 4-2	Expert's opinion
Expenditure ratio during design phase at time t	$exp_D(t)$	%	2.8%	2.8%	2.8%	Expert's opinion
degree of overlap between design and construction phases	F	%	0%	0%	0%	-
Federal effective monthly interest rate,	i_F	%	0.33%	0.33%	0.33%	Expert's opinion
Municipal effective monthly interest rate	i_M	%	0.45%	0.45%	0.45%	KPMG
Municipal effective monthly short-term investment interest rate	$i_{Mshorterm}$	%	0.13%	0.13%	0.13%	Expert's opinion
Private sector effective monthly interest rate	i_P	%	N/A	0.56%	0.56%	KPMG
Provincial effective monthly interest rate	i_{PR}	%	0.39%	0.39%	0.39%	Expert's opinion
Private sector equity ratio	r_{e_P}	%	0%	0%	5%	KPMG
Municipal debt ratio	r_{d_M}	%	100%	90%	70%	KPMG
Private sector debt ratio	r_{d_P}	%	0%	10%	25%	KPMG
Construction period under normal conditions	T_{Cb}	month	48	48	48	KPMG

Design period under normal conditions	T_{Db}	month	36	36	36	KPMG
Inflation effective monthly rate	θ	%	0.25%	0.25%	0.25%	KPMG

Table 4-1 Investment parameter data for Lions Gate Secondary Wastewater Treatment Plant

As shown in Figure 4-2, a uniform cash flow during the design period has also been assumed. Thus, the design cost is distributed uniformly over the design period, though, the construction cash flow varies in each period. The construction expenditure rate, as a percentage of constant cumulated construction cost, C_{C0}, is provided in Table 4-2.

Construction period in months	$exp_{C0}(t)$
1-9	1%
10-13	2%
14-19	3%
20-25	4%
26-29	3%
30-39	2%
40-48	1%

Table 4-2 Monthly expenditure rate in constant dollars during construction of the Lions Gate Secondary Wastewater Treatment Plant

Senior government Contribution agreement parameters						
Name	**Symbol**	**Unit or reported as**	**DBB**	**DBF**	**DBFOM**	**Source**
Federal contribution ratio at time t	R_F	%	30%	30%	30%	Expert's opinion
Provincial contribution ratio at time t	R_{PR}	%	30%	30%	30%	Expert's opinion
Eligibility ratio	r_{el}	%	85%	85%	85%	Expert's opinion

Table 4-3 Senior government contribution agreement parameter date of the Lions Gate Secondary Wastewater Treatment Plant

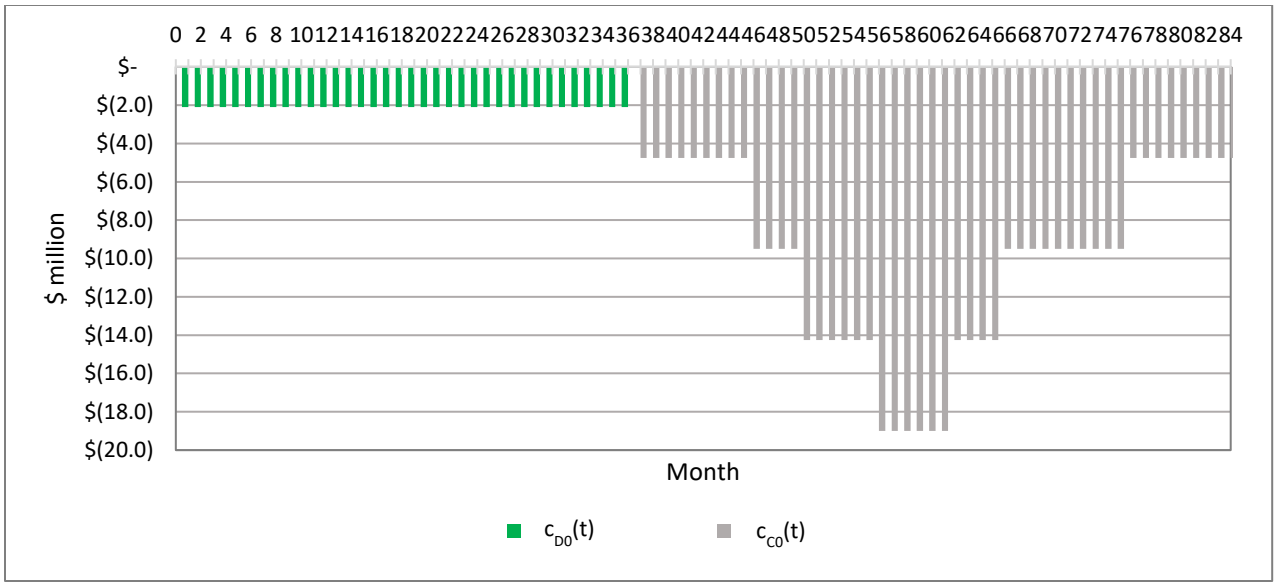

Figure 4-2 Design and construction expenditures of Lions Gate Secondary Wastewater Treatment Plant

4.2.1 Timing of Senior Government Contribution Payments

Regarding the timing of contribution payment to the client, to explore the two extremes of the contribution payment timing, front-end loaded ($r_{F\ or\ PR}(t = 0) = 1$, and back-end loaded ($r_{F\ or\ PR}([(1 - F) * T_D + T_C] + 1) = 1$ payments are investigated. In the former scenario, the senior levels of government contribute upon project approval, before the start of the design phase, while in the latter, the client receives the contribution payment after construction completion. In this case, the client is reimbursed for the costs after submitting expense claims. This increases the need for interim financing. For front-end-loaded contributions, it is assumed that the contribution payment is received by client at time zero, $t = 0$, while in the case of back-end loaded payment, it is received at the end of the construction phase at 85th ([36+48]+1) month, t_{85}. Design and construction phases are sequential, then the degree of overlap between these phases, F is equal to zero.

4.3 Model Results

The performance metrics explored include:

1. total project cost incurred by the client, TPC_M (inclusive of portion of design and construction costs financed by the municipal government borrowing, $\sum d_M$, interest paid on municipal government debt during design and construction phases, IDC_M, and interest accumulated on private sector debt during design and construction phase, IDC_P).
2. Interest expense during the design and construction phases from the viewpoint of client, federal and provincial government and the contractor, IDC_M, IDC_F, IDC_{PR}, and IDC_P, respectively.

Sections 4.4.1 and 4.4.2 discuss the sensitivity of the aforementioned performance metrics to the terms of contribution agreement, specifically:

1. timing of contribution payments,
2. the cost-sharing ratio of federal and provincial government contribution payments, and
3. eligibility ratio.

4.4 Cash Flow Diagrams of Lions Gate Secondary Wastewater Treatment Plant

Figures 4-3 to 4-13 demonstrate the Lions Gate Secondary Wastewater Treatment Plant cash flow diagrams to represent the flow of money in each month from different project participants viewpoint, including, the municipal government, private sector, federal and provincial governments.

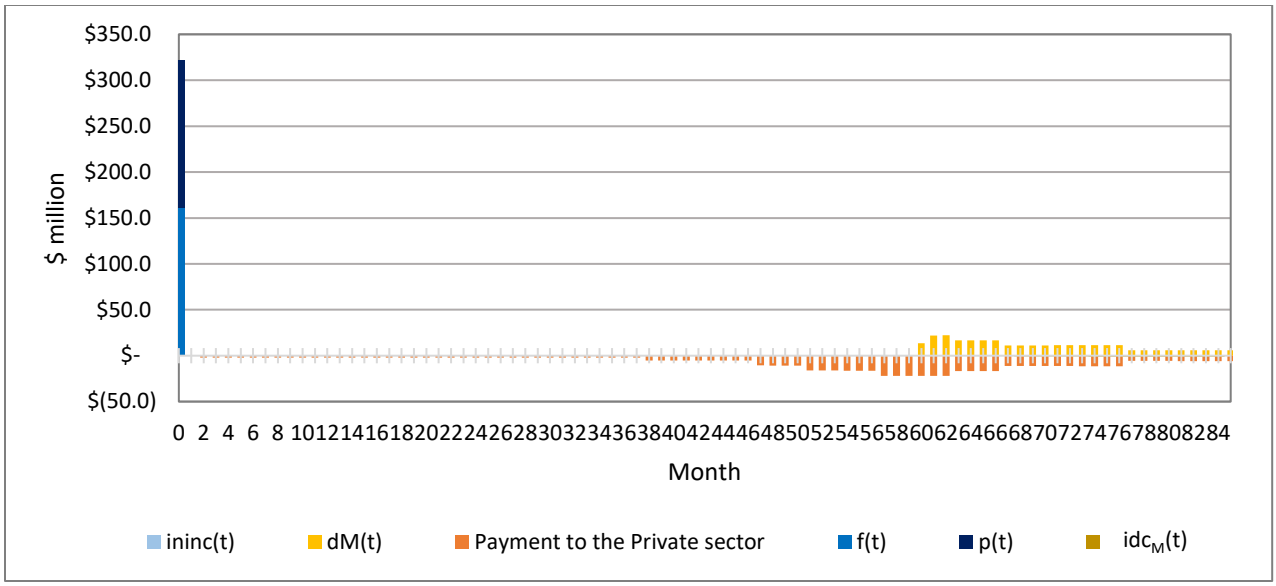

Figure 4-3 Cash flow diagram fr om the perspective of the municipal government with front-end loaded contribution payments from the senior levels of government under DBB procurement mode- Lions Gate secondary WWTP

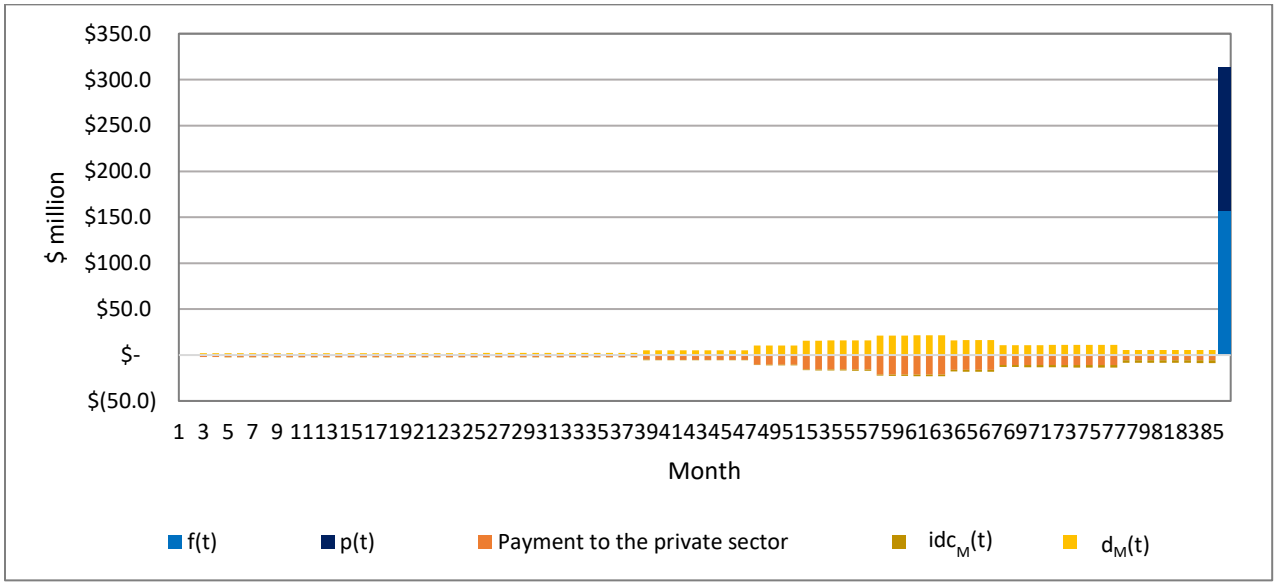

Figure 4-4 Cash flow diagram from the perspective of the municipal government with back-end loaded contribution payments from the senior levels of government under DBB procurement mode- Lions Gate secondary WWTP

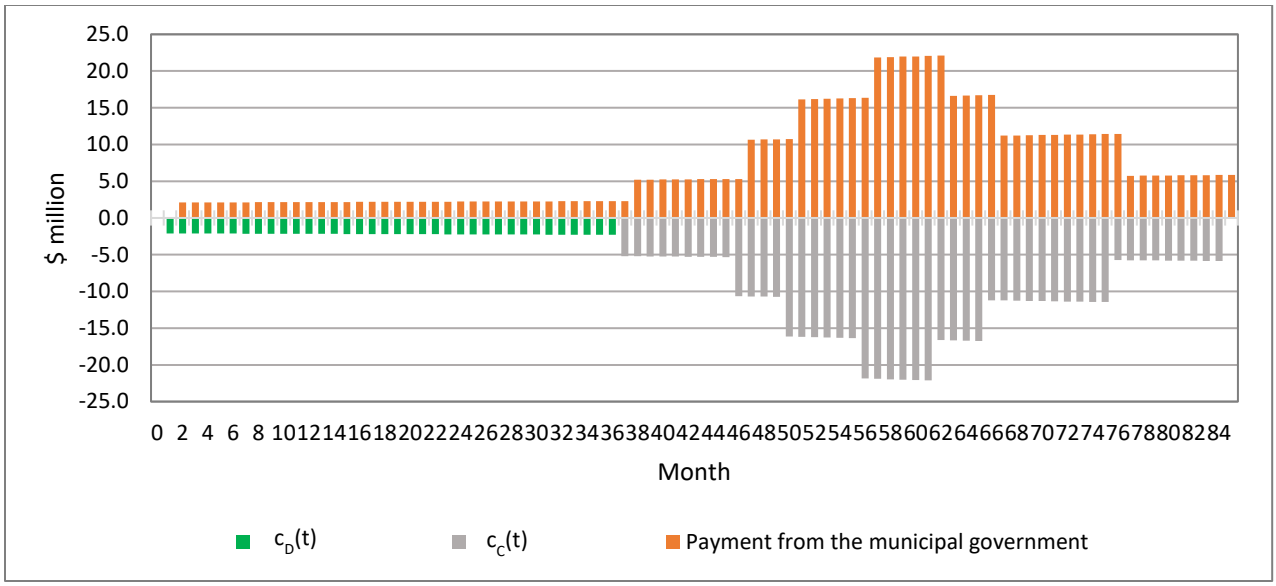

Figure 4-5 Cash flow diagram from the perspective of the private sector with front-end loaded/ back-end loaded contribution payments from the senior levels of government under DBB procurement mode- Lions Gate secondary WWTP

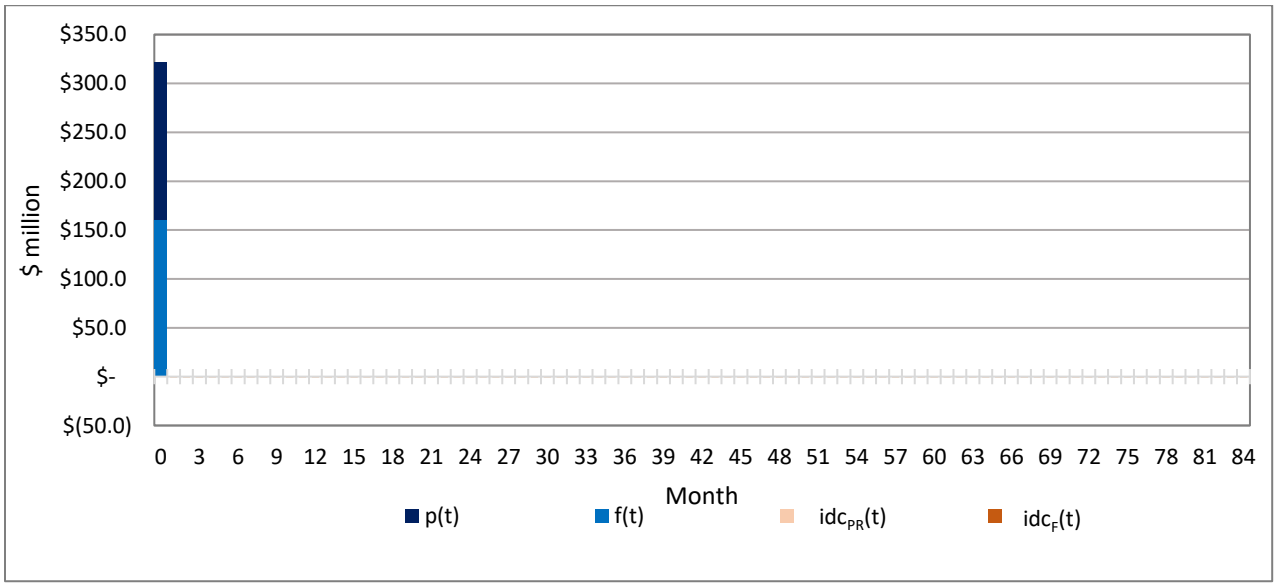

Figure 4-6 Cash flow diagram from the perspective of the federal and provincial governments with front-end loaded contribution payments to the municipal government under DBB procurement mode- Lions Gate secondary WWTP

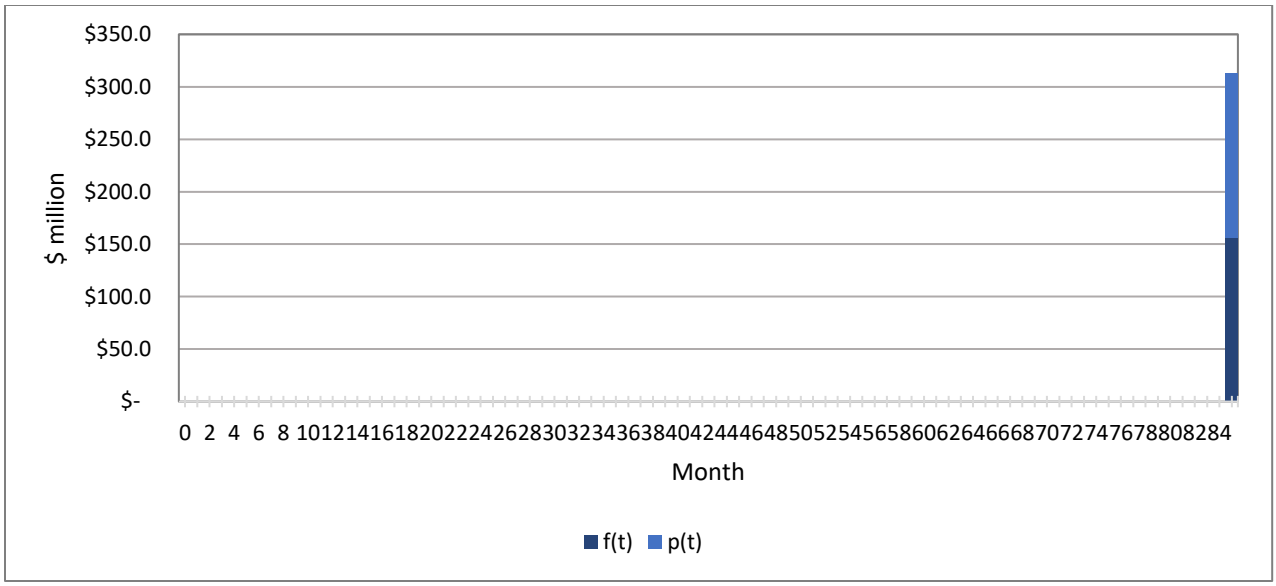

Figure 4-7 Cash flow diagram from the perspective of the federal and provincial governments with back-end loaded contribution payments to the municipal government under DBB procurement mode- Lions Gate secondary WWTP

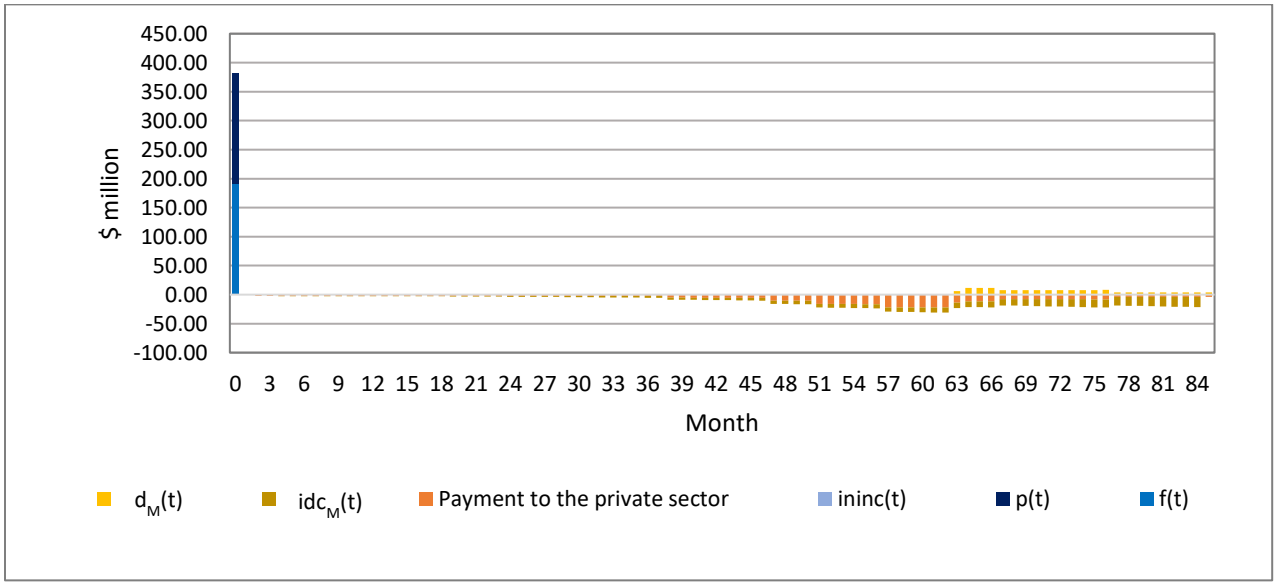

Figure 4-8 Cash flow diagram from the perspective of the municipal government with front-end loaded contribution payments from the senior levels of government under DBF/DBFOM procurement mode- Lions Gate secondary WWTP

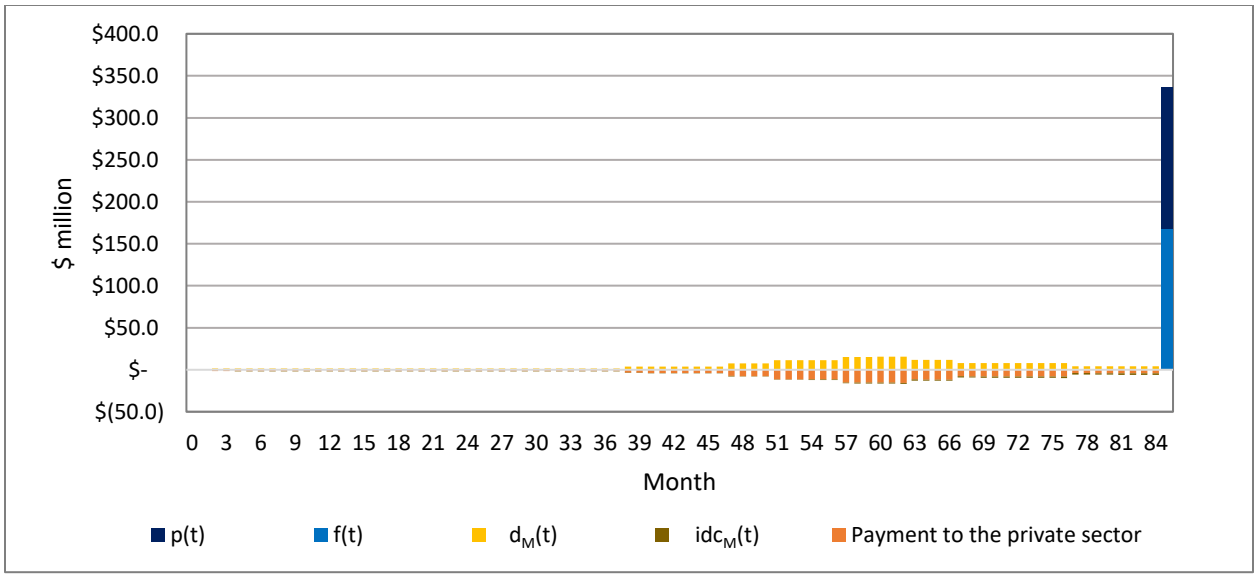

Figure 4-9 Cash flow diagram from the perspective of the municipal government with back-end loaded contribution payments from the senior levels of government under DBF/DBFOM procurement mode- Lions Gate secondary WWTP

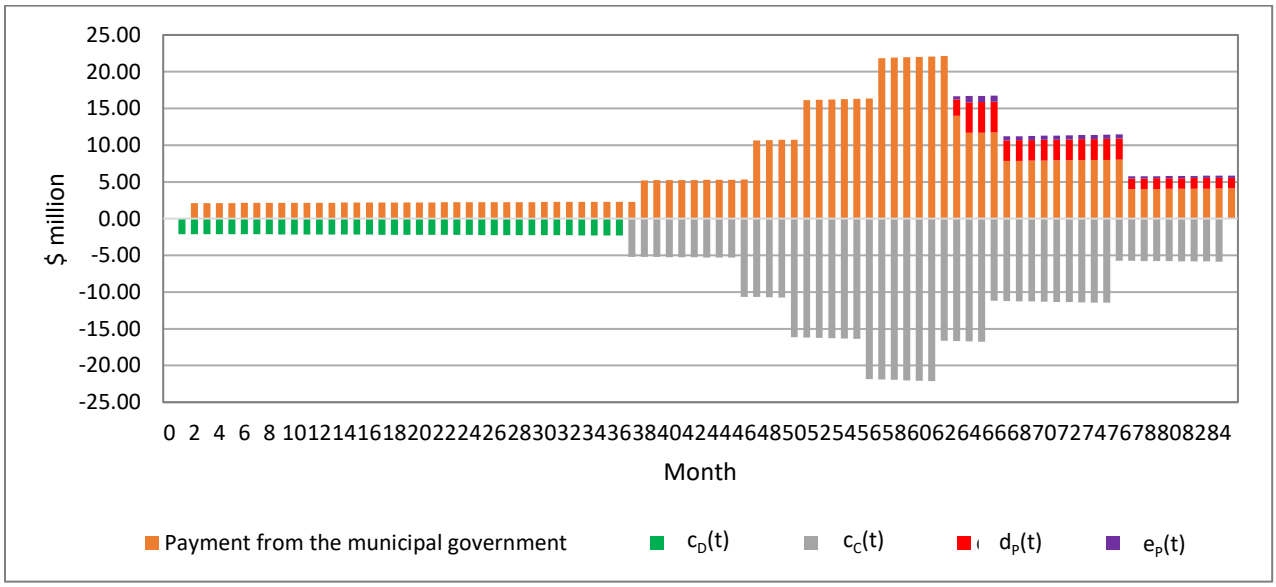

Figure 4-10 Cash flow diagram from the perspective of the private sector with front-end loaded contribution payments from the senior levels of government under DBF/DBFOM procurement mode- Lions Gate secondary WWTP

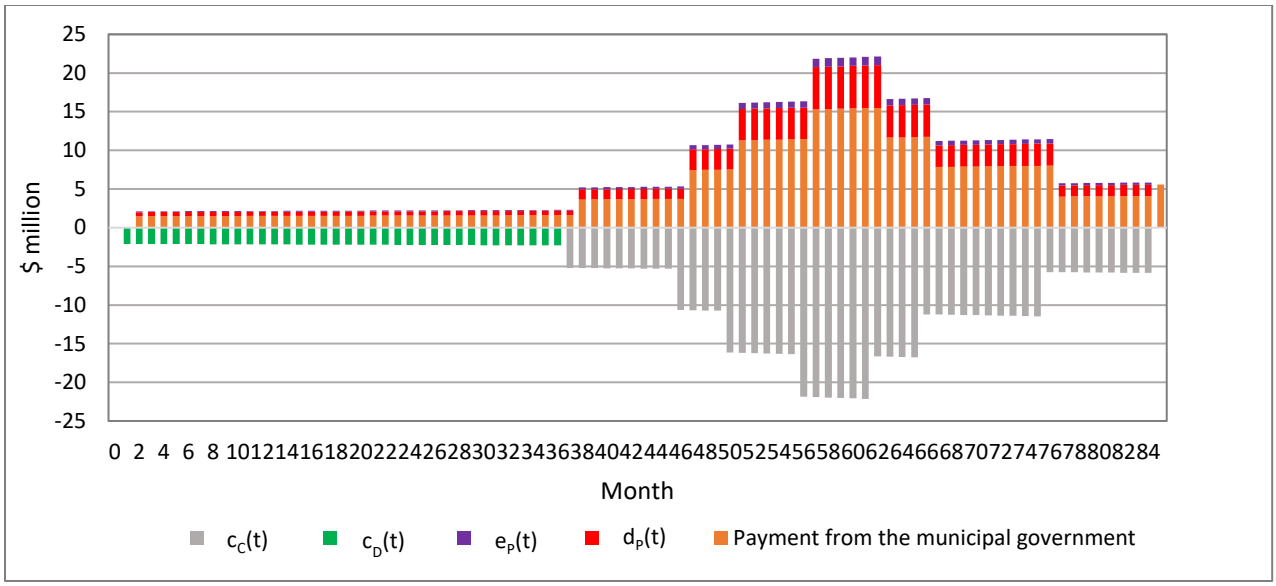

Figure 4-11 Cash flow diagram from the perspective of the private sector with back-end loaded contribution payments from the senior levels of government under DBF/DBFOM procurement mode- Lions Gate secondary WWTP

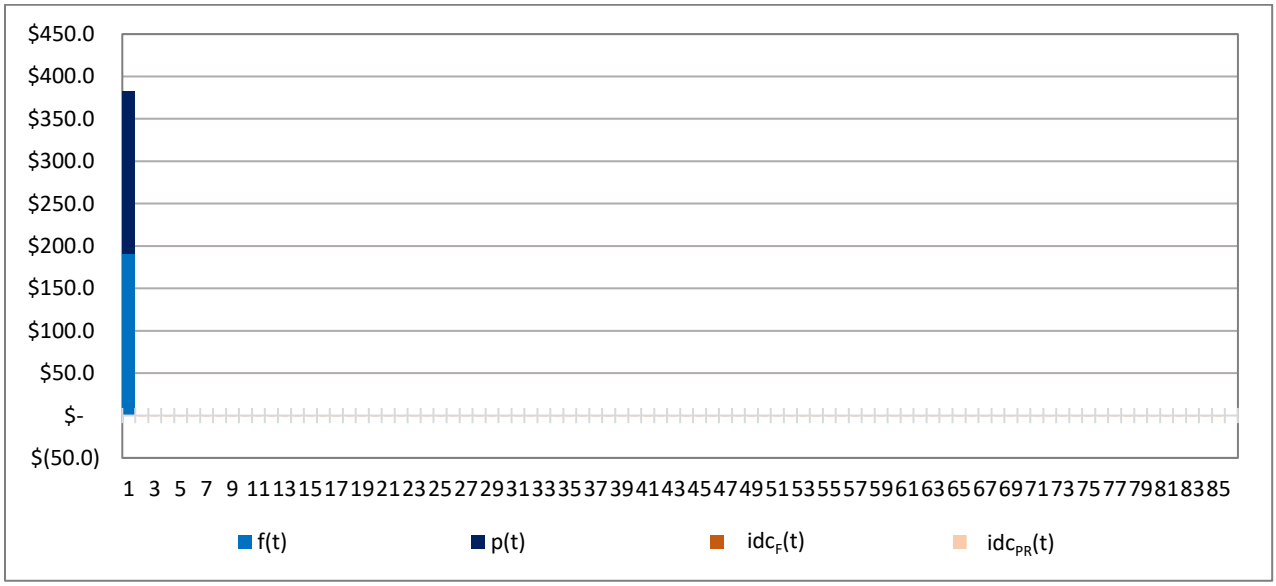

Figure 4-12 Cash flow diagram from the perspective of the federal and provincial governments with front-end loaded contribution payments to the municipal government under DBF/DBFOM procurement mode- Lions Gate secondary WWTP

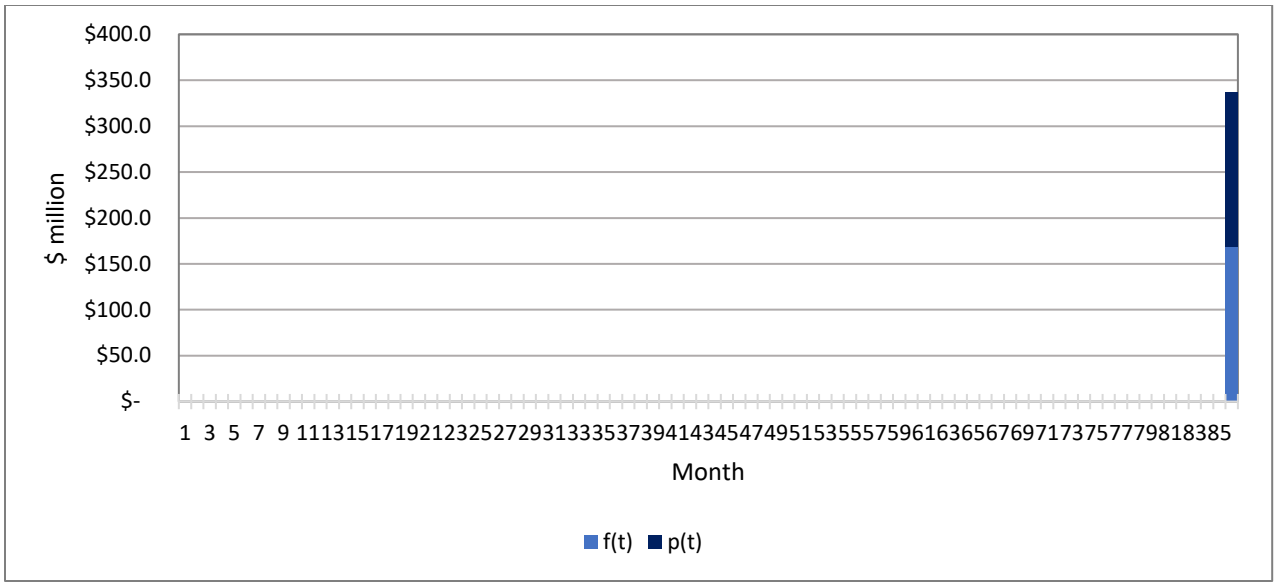

Figure 4-13 Cash flow diagram from the perspective of the federal and provincial governments with back-end loaded contribution payments to the municipal government under DBF/DBFOM procurement mode- Lions Gate secondary WWTP

4.4.1 Sensitivity of IDC_M, IDC_F, IDC_{PR}, IDC_P, and TPC_M to the Timing of Contribution Payments

Table 4-4 presents the sensitivity analysis results for interest expenses during design and construction phases from each project participants' perspective for the three procurement modes examined. As illustrated in the table, for all procurement modes examined, as the timing of contribution payments shifts to the end of conduction period, while other model parameters are fixed. IDC_M, IDC_P , and TPC_M increase while IDC_{PR} and IDC_F decrease. These results demonstrate the fact that with back-end loaded contribution payments, the need for interim financing by the municipal government and the private sector increases, which results in an increase in the value of interest expense incurred by the municipal government and the private sector and total project cost incurred by the client. On the other hand, from the perspective of the federal and provincial governments, financing costs are incurred under front-end loaded contribution payments during

the design and construction period. Since the scope of this study is to model the financing cost from the view point of project participants until the end of the construction phase, the financing cost incurred by the federal and provincial governments with back-end loaded contribution payments (i.e., after the end of construction phase) is not considered. It should be noted that, since, under the DBB procurement mode, the private sector does not provide any financing services, a sensitivity analysis for IDC_P is not conducted.

Another important observation is that cost of borrowing varies among the project participants. The private sector has the highest interest rate while the federal government has the lowest interest rate. The financing cost is dependent on both the interest rate and the financing ratio at which each level of government finances the project. Here, since the private sector provides debt for only 25% (see Table 4-1) of the financing shortfall compared to the municipal government which finances 70% of financing shortfall, the IDC_P is lower than IDC_M. For example, under DBF or DBFOM procurement modes with back-end loaded contribution payments, the IDC_P is equal to $28.7 million, which is lower than IDC_M of $55.7 million, because the private sector debt ratio is lower that the municipal debt ratio while the private sector interest rate is higher than municipal government (i.e., $i_P = 0.56\% > i_M = 0.45\%$).

The most important takeaway from Table 4-4 is that the timing of the federal and provincial government contribution payments has a direct effect on the financing cost of project participants. For instance, back-end loaded contribution payments lead to higher project costs as they shift the financing responsibility to the municipal government and the private sector which have a higher cost of borrowing compared with the federal and provincial government and because borrowing commences with project inception. It is important to see the problem from different viewpoints to consider their values and objectives. These results may provide useful insights for policy makers

who decide on the timing of contribution payments to the client in an infrastructure project, while they intend to make the project affordable for end-users who pay to use the infrastructure. This is particularly the case when interest rate differentials are high. However, the decision regarding the timing of contribution payments should be made considering simultaneously the numbers in Table 4-4 with other objectives that stated in Tables 3-1 to 3-4. For example, the senior levels of government may prefer to make back-end load contribution payments to incentivize the client's performance. Herein, only four performance metrics were explored to measure the fulfillments of those objectives. Making informed decisions requires considering simultaneously more than four objectives.

	DBB					**DBF / DBFOM**				
Timing of contribution payments	IDC_P	IDC_M	IDC_{PR}	IDC_F	TPC_M	IDC_P	IDC_M	IDC_{PR}	IDC_F	TPC_M
Front-end loaded, t_0	n/a	18.9	52.7	44.6	309.0	6.5	13.0	53.3	45.1	220.0
Back-end loaded, t_{85}	n/a	79.5	0	0	704.7	28.7	55.7	0	0	522.0

Table 4-4 Sensitivity of IDC_M, IDC_F, IDC_{PR}, IDC_P, and TPC_M to change in timing of contribution payments under the DBB, DBF, and DBFOM procurement modes

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4.4.2 Sensitivity of IDC_M, IDC_F, IDC_{PR}, IDC_P, and TPC_M to the Cost-Sharing Ratio and Eligibility Ratio of the Federal Government Contribution Agreement

Other terms of contribution agreements are the cost-sharing ratio and eligibility ratio as a percentage of project total capital cost. In this section, the sensitivity of interest expense during design and construction phase from the project participants' perspectives, and the total project cost

incurred by the client, to the federal government cost-sharing and eligibility ratio, R_F and el, respectively, is provided. The sensitivity results of the performance metrics to R_F are provided in Table 4-5. The R_F changes in the range of lower bound equal to zero percent and upper bound equal to 70 percentage (100% minus provincial contribution equal to 30%).

As shown in Table 4-5, under all procurement modes examined, when R_F increases from 0% to 70%, IDC_M, IDC_P, and TPC_M decrease in value, while IDC_F increases. The reason is that the higher federal government cost-sharing ratio results in higher interest expenses during the design and construction phase. IDC_F starts from zero, when the federal government does not contribute to the project, and increases gradually to $104.1 million with a 70% cost-sharing ratio. On the other hand, higher federal cost-sharing ratios decrease the need for interim financing by the municipal government and the private sector which subsequently reduce IDC_M, IDC_P, and TPC_M. It should be noted that since under the DBB procurement mode the private sector does not provide any financing services, no sensitivity analysis for IDC_P was conducted.

		DBB				DBF / DBFOM			
	R_F	IDC_P	IDC_M	IDC_F	TPC_M	IDC_P	IDC_M	IDC_F	TPC_M
	0%	n/a	41.1	0	504.2	14.3	28.6	0	365.7
	10%	n/a	32.9	14.9	438.5	11.4	22.8	15.0	316.5
	20%	n/a	25.5	29.7	373.5	8.8	17.6	30.0	267.9
Base case	30%	n/a	18.9	44.6	309.0	6.5	13.0	45.1	220.0
	40%	n/a	12.9	59.5	245.0	4.4	8.8	60.1	172.7
	50%	n/a	7.8	74.3	181.5	2.6	5.2	75.1	126.0
	60%	n/a	3.6	89.2	118.8	1.2	2.3	90.1	80.3
	70%	n/a	0.9	104.1	57.0	0.3	0.5	105.2	35.7

Table 4-5 Sensitivity of IDC_M, IDC_F, IDC_P, and TPC_M to change in the federal cost-sharing ratio under the DBB, DBF, and DBFOM procurement modes

Illustrated in Table 4-6, is the sensitivity analysis results of interest expenses and total project cost incurred by the client to the eligibility ratio of contribution agreements. The eligibility ratio changes in a range from 0%, when the total capital cost of the project is ineligible for senior government contribution, to 100%, when the total capital cost is considered eligible for senior government contributions. For example under the DBF procurement mode, the zero percent eligibility ratio makes IDC_F and IDC_{PR} equal to zero while under the 100% eligibility ratio, IDC_F and IDC_{PR} reach their highest value of $53.0 million, and $62.7 million respectively. However, when the el increases, IDC_M, IDC_P, and TPC_M decrease, this is because, as higher percentage of capital cost becomes eligible for senior government contribution, the need for the municipal and private sector financing falls.

		DBB					DBF / DBFOM				
	el	IDC_P	IDC_M	IDC_{PR}	IDC_F	TPC_M	IDC_P	IDC_M	IDC_{PR}	IDC_F	TPC_M
	0%	n/a	79.5	0	0	710.6	28.7	55.7	0	0	526.1
	25%	n/a	53.0	13.1	15.5	586.4	18.5	36.9	15.7	13.3	428.1
	45%	n/a	39.6	27.9	23.6	492.5	13.7	27.5	28.2	23.9	357.0
	65%	n/a	28.4	40.3	34.1	400.2	5.7	14.8	24.4	20.3	659.8
Base case	85%	n/a	18.9	52.7	44.6	309.0	6.5	13.0	43.3	45.1	220.0
	100%	n/a	12.6	62.5	52.5	241.2	4.3	8.5	62.7	53.0	169.9

Table 4-6 Sensitivity of IDC_M, IDC_F, IDC_{PR}, IDC_P, and TPC_M to change in the eligibility ratio under the DBB, DBF, and DBFOM procurement modes

Similar to the timing of contribution payments, when senior government policymakers want to decide on an appropriate cost-sharing ratio or the type of costs which are eligible for contributions to have an efficient investment in infrastructure, it is crucial to consider the problem from different perspectives and observe how decisions influence the financing cost incurred by various project participants. One policy might be in the interest of the senior government, while it incurs more costs to the lower level of government.

The results in Sections 4.4.1 and 4.4.2 are highly affected by the assumption that the client makes drawdowns on financing sources, giving priority to contribution payments from federal and provincial governments and the interest income on un-used contribution funds. If this assumption were changed, i.e., the client was to require that the private sector borrowed money from the start of the project, the IDC_P, would be insensitive to the terms of the contribution agreements examined herein.

4.4.3 Relative Significance of Terms of Contribution Agreements

In Section 4.3.1 and 4.3.2, the sensitivity of each performance metric to the terms of contribution agreements was explored. In this section, the relative significance of these terms is discussed. The significance is evaluated for each term of contribution, by examining each output metric and calculating the following:

$$\frac{Total\ change\ output\ metric\ over\ all\ variations\ of\ a\ term\ of\ contribution}{Maximum\ output\ metric\ value\ for\ this\ contribution\ term} * 100$$

The goal is to explore which terms of contribution agreement have a more significant impact on the interested output metrics. The results can aid those who negotiate the terms of contribution agreements with the senior levels of governments by emphasizing the important terms, which have a more significant impact on the output metrics.

For timing of contribution agreements, the actual decrease or increase is measured when back-end load contribution payments are changed to front-end loaded contribution payments. For r_F and el, the actual decrease or increase is measured when it varies from 0% to 70% and 100%, respectively.

	IDC_P	IDC_M	IDC_F	IDC_{PR}	TPC_M
Timing	77%	76%	100%	100%	58%
r_F	97%	98%	100%	n/a	90%
el	84%	85%	100%	100%	68%

Table 4-7 : The percent increase or decrease of performance metrics as result of terms of contribution agreements variation between upper and lower bound

The results in Table 4-7 show that, from the perspective of the municipal and private sector, the cost-sharing ratio of the federal government has a more significant impact on their interest expense as well as the municipal government total project cost. On the other hand, from the perspective of the federal and provincial government, changes in the timing, cost-sharing ratio, and eligibility ratio, incur new costs which they wouldn't bear if the contribution payments were back-end loaded or r_F and el were zero. These results are especially beneficial for municipal governments as they can shed light on the approach these parties should take in negotiating with senior levels of government, and in identifying preferred ways to respond to or negotiate terms of contribution agreements.

4.5 Model Consistency

The sensitivity analysis presented above demonstrates an acceptable consistency between the results and what one would expect to see in practice. However, in order to further demonstrate model consistency, i.e., to evaluate whether output metrics change in the direction and at a magnitude that would be reasonable, in response to corresponding changes in model parameter values, some of the model parameters are varied by +/- 20% of their base values to observe the changes in output metrics. The parameters varied include the inflation rate, cumulative construction cost in constant dollars, construction period, and interest rate of municipal government, θ, C_{C0}, T_C, and i_M, respectively. The metric IDC_M under the DBB procurement mode with back-end loaded contribution payments is chosen for this analysis. The aforementioned parameters are changed sequentially, while all other parameters are fixed.

As shown in Table 4-8, IDC_M shows higher sensitivity to i_M, C_{C0}, and T_C which are logically the most important parameters in the model. Growth in the interest rate or cost of municipal

government borrowing increases the municipal government financing cost. Also, as the C_{C0} increases, the need for municipal financing increases which subsequently raises the financing costs for municipal government. When the construction goes overtime, it increases the interest payment duration which rises IDC_M. However, IDC_M shows lower sensitivity to changes in the inflation rate which is a less important parameter compared with i_M, C_{C0}, and T_C. Figure 4-3 compares the range in which IDC_M varies if each of the parameters examined change by +/- 20% of their base values.

This analysis demonstrates that the model shows higher sensitivity to the logically most important parameters, and lower sensitivity to the logically least important parameters, which indicates the soundness of the model.

Parameters	**20% increase**	**20% decrease**
i_M	+20%	-20%
C_{C0}	+14%	-14%
T_C	+8%	-19%
θ	+2%	-2%

Table 4-8 Sensitivity of IDC_M to changes in θ, C_{C0}, T_C, and i_M

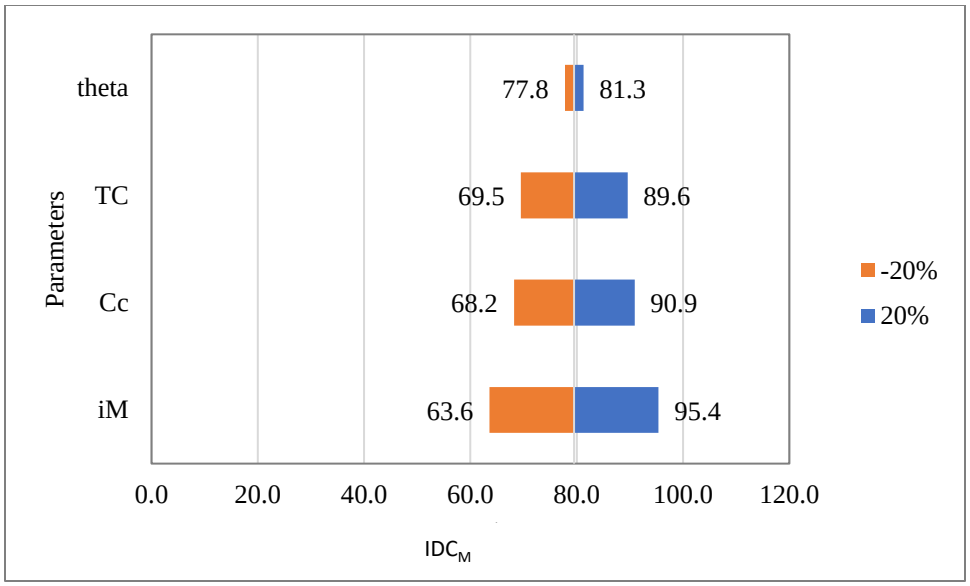

Figure 4-14 Tornado diagram of sensitivity of IDC_M to changes in θ, C_{C0}, T_C, and i_M

Chapter 5: Conclusion and Future Works

Since 2002, the federal government increased its role in infrastructure financing in response to public demand for infrastructure deficit reduction in Canada by introducing a series of funding programs (Jackson, 2015). The federal infrastructure programs have become a permanent feature of Canadian fiscal federalism (Dahlby & Jackson, 2015). The federal government pursues specific goals and objectives through increasing investment in public infrastructure. Objectives which are set by the Constitution Act mandate the federal government to support expenditures which provide equal opportunities, enhance economic development for decreasing inequality in opportunities, and provide essential public services with consistent quality. One of the government's key instruments in fostering its objectives and priorities are transfer payments, including grants and contributions. They contribute to building a strong society and a competitive country which is inclusive and respectful of Canadian values and furthers Canadian aims through enabling and engaging a broad variety of skills and resources outside the federal government.

The government of Canada sets out certain policies for design, delivery and management of transfer payment to comply with its objectives and priorities and ways which are "fair, accessible and effective for all involved – departments, applicants and recipients – all of whom have important contributions to make in achieving the objectives of the government and in furthering Canadian aims (Policy on Transfer Payments, 2015)."

This study explores different arrangements of contribution agreements, as a policy instrument, in terms of timing of contribution payments, the cost-sharing ratio, and the eligibility ratio in fulfillment of project participant values and objectives. From the broad list of project participant objectives developed in Tables 3-1 to 3-4, this thesis explored the sensitivity of four performance metrics, including: the interest expense on debt financing from the perspective of client, the senior

government and private sector, and total project cost incurred by the client, to contribution agreement terms under DBB (Design-Bid-Build), DBF (Design-Build-Finance), and DBFOM (Design-Build-Finance-Operate-Maintain) project procurement modes. Through the parametric cash flow model developed in Chapter 3, the effect of changes in contribution agreement terms on the performance metrics under the procurement modes examined, is measured. The model is tested on the case study of the Lions Gate Secondary Wastewater Treatment Plant project along with a sensitivity analysis of performance metrics versus change in model parameters. The results show that in the case of front-end loaded contribution payments, the financing cost of the municipal government and private sector, and the total project cost incurred by the municipal government, substantially decrease while the financing costs incurred by the federal and provincial government during design and construction increase. In the case of back-end loaded contribution, the need for interim financing by the client and the private sector increases which raises the financing costs of these participants. On the other hand, the federal and provincial government incur no financing cost during the design and construction period.

The financing cost of project participants is also highly sensitive to the cost-sharing and eligibility ratio of senior government contributions. As the cost-sharing and eligibility ratio of senior government contributions increase, the need for interim financing by the client and private sector decreases and the interest expenses on debt financing decrease, while the financing costs for the federal and provincial government increase.

Finally, the results demonstrate that the performance metrics examined are highly sensitive to the terms of contribution agreements. The results of this research provide input that may be useful for those who sets policies on how the federal government can make an efficient investment in public

infrastructure, and not only achieve the broad policy objectives of the federal government, but also consider the values of all other participants who contribute to building an infrastructure.

Further work, to advance the findings of this thesis, should include the comparison of procurement modes examined in terms of their effectiveness for achieving a specific objective. I lay the groundwork for extending the model presented in Chapter 3 to support the decision of what type of procurement mode to select to achieve a specific objective. Moreover, the model measures only four performance metrics of the list of those presented in Tables 3-1 to 3-4. One could measure more objectives from different perspectives to have a more insightful analysis.

This research explores the contribution agreements in terms of timing of contribution payment, the cost-sharing ratio, and the eligibility ratio. Another term of contribution agreement that one can consider to advance the findings of this thesis is the length of the approval process, i.e., the duration of the period that it takes the senior government to approve its contribution to the project. Extended approval periods increase the risk of cost overruns due to price escalation which will incur higher costs to the senior government as well as other project participants.

Moreover, to enhance the findings of this thesis, an analysis of the trade-offs between meeting the different objectives of the participants, i.e., improving the satisfaction of one objective may diminish the ability to satisfy another, can be informative and illuminating. The model may be used to provide values for the objectives under different funding arrangements and these values comprise the Pareto Optimal front for the set of decisions made in funding projects.

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Appendix 1: The Definition of Ultimate Recipients

The following section provides the definition of ultimate recipients identified in Canada-British Columbia Integrated Bilateral Agreement for The Investing in Canada Infrastructure Program (2018).

"Ultimate Recipients

i. British Columbia may be an Ultimate Recipient and may distribute Canada's contribution funding to its own Projects and subject to the terms and conditions of this Agreement.

ii. British Columbia may further distribute Canada's contribution funding to the following Ultimate Recipients for Projects and subject to the terms and conditions of this Agreement:

a) A local or a regional government established by or under provincial statute;

b) A public sector body that is established by or under provincial statute or by regulation or is wholly-owned by British Columbia, or a local or regional

government;

c) When working in collaboration with a local government, a public or not-for-profit institution that is directly or indirectly authorized, under the terms of provincial or federal statute, or royal charter, to deliver post-secondary courses or programs that lead to recognized and transferable post-secondary credentials;

d) A private sector body, including for-profit organizations and not-for-profit organizations. In the case of for-profit organizations, they will need to work in collaboration with one or more of the entities referred to above or an Indigenous government listed below; and

e) The following Indigenous Ultimate Recipients:

i. A band council within the meaning of section 2 of the Indian Act;

ii. A First Nation, Inuit or Métis government or authority established pursuant to a self-government agreement or a comprehensive land claim agreement between Her Majesty the Queen in Right of Canada and an Indigenous people of Canada, that has been approved, given effect and declared valid by federal legislation;

iii. A First Nation, Inuit or Métis government that is established by or under legislation whether federal or provincial that incorporates a governance structure; and

iv. A not-for-profit organization whose central mandate is to improve Indigenous outcomes, working in collaboration with one or more of the Indigenous entities referred to above, a local government, or British Columbia."

Appendix 2: Infrastructure Canada Contribution Programs Overview Since 2002

Program	Announced Allocation	$ Available for Projects (Initial)	$ Approved	$ Paid Out	$ Unspent
PTIS	$20,109,797,092	$18,901,444,756	$2,725,916,689	$0	$18,901,444,756
GIS	$9,674,833,481	$8,957,498,254	$526,326,208	$0	$8,957,498,254
RNIS	$1,998,186,983	$1,964,893,630	$8,479,275	$82,638	$1,964,810,992
CCRIS	$1,345,982,446	$1,323,891,075	$12,619,368	$3,851,761	$1,320,039,314
AEF	$400,000,000	$400,000,000	$30,000,000	$0	$400,000,000
TWRI	$384,166,667	$384,166,667	$384,166,667	$0	$384,166,667
DMAF	$2,000,000,000	$1,991,261,900	$247,500,000	$0	$1,991,261,900
PTIF	$3,400,000,000	$3,362,375,061	$3,177,640,837	$493,654,065	$2,868,720,995
CWWF	$2,000,000,000	$1,970,443,142	$1,916,388,896	$714,571,545	$1,255,871,596
NRP	$9,000,000,000	$9,434,569,698	$6,921,220,521	$738,880,464	$8,695,689,234
NIC	$4,000,000,000	$1,708,200,000	$1,646,078,924	$23,764,321	$1,684,435,679
MIC	$6,499,272,000	$6,625,380,681	$6,566,614,561	$5,242,054,131	$1,383,326,550
SCF	$1,000,000,000	$1,544,896,331	$1,374,120,494	$376,702,336	$1,168,193,995

Program	Announced Allocation	$ Available for Projects (Initial)	$ Approved	$ Paid Out	$ Unspent
GIF	$1,000,000,000	$744,244,336	$735,594,547	$433,786,223	$310,458,113
CC	$1,054,818,000	$1,023,220,361	$1,013,219,189	$971,007,654	$52,212,707
LUCC	$200,000,000	$194,000,000	$193,714,652	$95,051,826	$98,948,175
RPC	$14,250,000	$3,100,000	$766,389	$766,389	$2,333,611
ITH	$200,000,000	$200,000,000	$200,000,000	$194,000,000	$6,000,000
CSIF	$4,300,000,000	$4,650,489,481	$4,620,864,244	$4,542,880,559	$107,608,922
BIF	$600,000,000	$592,017,150	$599,536,349	$575,890,521	$19,944,668
MRIF*	$1,200,000,000	$981,441,745	$980,887,219	$980,887,219	-
ISF*	$4,000,000,000	$3,708,358,763	$3,320,859,201	$3,320,859,201	-
CC Top-Up*	$500,000,000	$495,094,092	$462,042,486	$462,042,486	-
G8LF*	$50,000,000	$50,000,000	$44,870,037	$44,870,037	-
NIKC*	$45,000,000	$247,303	$186,989	$186,989	-
NRT*	$25,000,000	$33,600,000	$32,823,235	$32,823,235	-
RKO*	$25,000,000	$8,868,101	$8,868,101	$8,868,101	-

Program	Announced Allocation	$ Available for Projects (Initial)	$ Approved	$ Paid Out	$ Unspent
Total	**$75,026,306,669**	**$71,253,702,526**	**$37,751,305,077**	**$19,257,481,701**	**$51,572,966,12**