Selection of P3 delivery methods for Sustainable Social Infrastructure Projects Using the Analytical Hierarchical Process

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Abstract

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Nita Semgalawe

This thesis studies the necessary shift in screening practices of public-private partnerships (P3) projects in Canada, moving beyond traditional qualitative criteria to include broader environmental, social, and governance (ESG) project objectives. The current P3 screening, while effective, needs adaptation to align with Canadian societal and environmental infrastructure goals. In response, this thesis focuses on three objectives aimed at improving social infrastructure P3 procurement and promoting sustainable and responsible project management practices for these projects. Firstly, it identifies and describes Canadian-specific ESG criteria important for ensuring responsible sustainability in delivering social infrastructure projects. Secondly, it develops an ESG-PPP screening matrix to evaluate social infrastructure projects based on responsible sustainability thresholds, determining their suitability for P3 procurement. Thirdly, it implements a multi-criteria analysis using the Analytic Hierarchy Process (AHP) to determine the most appropriate P3 model for social infrastructure projects, considering the identified ESG criteria and quantitative value-for-money criterion. The AHP-PPP selection tool is applied to three case studies analyzing two AHP scales to assess their consistency ratios and the reliability of the P3 selection results. The results indicate that the balanced-n scale exhibit lower inconsistency ratios compared to the fundamental AHP scale, and decisions on P3 options remained consistent across all case studies using both scales, suggesting that the Fundamental AHP scale remains reliable if decision-makers accurately reflect the relative importance of P3 options. Overall, this thesis addresses the increasing need for sustainable and responsible management of social infrastructure projects in Canada by integrating ESG factors into the current procurement process.

Acknowledgements

I am sincerely grateful to my supervisor, **Dr. Osama Moselhi**, for providing me with valuable guidance and unwavering support throughout the course of my research. His guidance has played an important role in shaping the depth and quality of this research work.

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Dedication

To

Juana, Dr. Zainab Semgalawe, and Dr. Kristina Lugangira, your support and encouragement have given me strength, purpose, and motivation.

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LIST OF ABBREVIATIONS

The Table below lists abbreviations and acronyms frequently used in this thesis. It does not include nonstandard acronyms used occasionally to abbreviate mathematical variables.

PDM	Project delivery model
PM	Project management
PPP/P3	Public-private partnership
ESG	Environmental, Social and Governance
VfM	Value for Money
MCA	Multi Criteria Analysis
AHP	Analytical Hierarchy Process
DB	Design-build
DBB	Design-bid-build
DBF	Design-build-finance
DBFM	Design-build-finance-maintain
DBFOM	Design-build-finance-operate-maintain
PR. DBFM	Progressive Design-build-finance-maintain
PR. DBFOM	Progressive Design-build-finance-operate-maintain
PPP-ESG	Public private partnership - Environmental, Social and Governance
AHP- PPP	Analytical Hierarchy Process- Public-private partnership
CCPPP	Canadian Council for Public private partnership
CBA	Community Benefits Agreement
LEED	Leadership in Energy and Environmental Design
CCDC	Canadian Construction Documents Committee
CAGBC	Canadian Green Building Council
TRUE	Total Resource Use and Efficiency
ZCB	Zero Carbon Building
NL	Newfoundland and Labrador
PEI	Prince Edward Island
VBA	Visual basics for Applications
PWGSC	Public Works and Government Service Canada
SMEs	Small and Medium Sized Enterprises

Chapter 1: Introduction

1.1. Overview

Growing concerns about climate change, social inequalities, and limited financial resources emphasize the urgent need for sustainable development in the construction industry. Canada's response involves implementing the Canada Investing Plan, directing funds to projects that foster inclusive communities, generate job opportunities, and develop robust infrastructure systems [1]. In 2021, over $71 billion has been allocated for key infrastructure areas like public transit, green projects, community facilities, rural development, and COVID-19 resilience [1] [2] [3]. This substantial financial commitment demonstrates that Canada is committed to prioritizing social and environmental aspects in infrastructure projects, with a primary focus on sustainable development.

Sustainable development, as defined by the Canadian Federal Sustainable Development Act, is the simultaneous fulfillment of present needs while preserving the capacity of future generations to meet their own needs [4] similar to the definition provided by the Brundtland Commission Report [5]. Thus, adopting a sustainable development approach when procuring infrastructure projects in Canada is important to ensure that projects are not only delivered within set budgets and timelines, but also contribute to the long-term preservation of the environmental, social, and economic well-being of future generations.

Social infrastructure projects constitute the largest proportion of the total infrastructure projects undertaken in Canada. They comprise physical facilities and spaces where can come together, engage in social activities, and access important services like education and healthcare. These spaces support human interaction, community engagement, and social development, making communities more livable and meaningful. They play an important role in meeting people's social needs, promoting connections, and enhancing overall well-being [6] [7] [8]. As seen in

Figures 1 and 2 below, they include hospitals, schools, public transit, housing, recreation, and culture buildings.

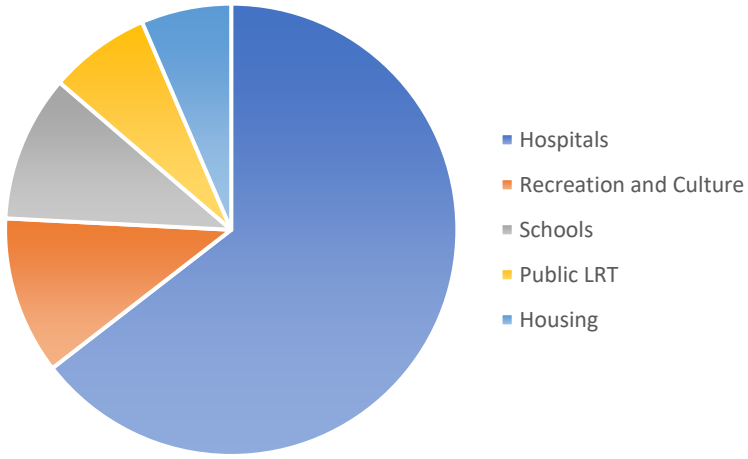


Figure 1. The number of completed social infrastructure projects in Canada by 2023 *[9]*.

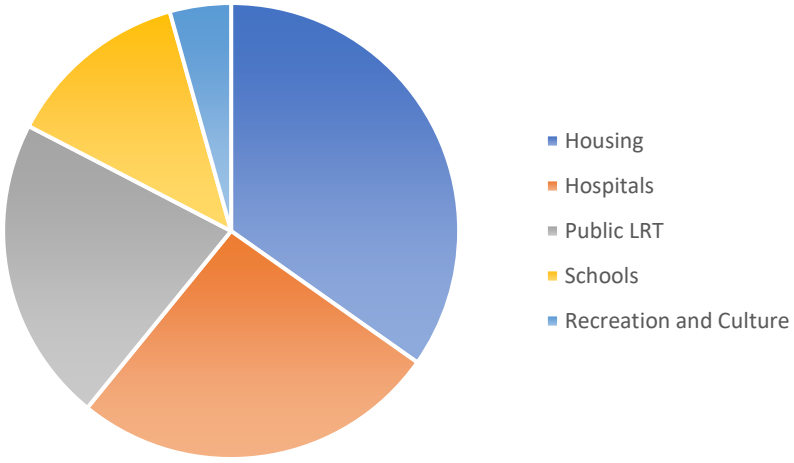


Figure 2. The number of pipeline social infrastructure projects in Canada from 2023 *[9]*.

The procurement process for social infrastructure projects follows a two-stage process. Initially, a qualitative assessment screens various project delivery models (PDM) against specific objectives established from the project's description and needs assessment. These objectives, in

conjunction with project constraints, serve as the evaluative criteria for the project delivery models. Table 1 below displays the existing most commonly used evaluating criteria for social infrastructures in Canada.

The second stage, known as the quantitative assessment, involves conducting a detailed VfM analysis on a shortlist of options that meet the qualitative project requirements. Both phases aim to compare the benefits and risks associated with potential project delivery models, evaluating their suitability for achieving the project objectives. However, the primary selection of the project delivery model takes place during the quantitative stage. This stage emphasizes quantitative factors, especially financial considerations.

Table 1. Existing P3 suitability criterion and sub-criteria for social infrastructure projects.

Existing Qualitative Criteria	Existing Qualitative Sub-Criteria	Existing Quantitative Criteria
Project characteristics and scope	1. Project size: 25-35 years, > $100 million 2. Project complexity and innovation need 3. Project phases and integration (O&M) 4. Project Type: New Construction	**Base costs:** Construction cost Operating cost Maintenance cost Lifecycle cost Competitive neutrality
Cost and historical factors	1. Project financing and funding need 2. Past project cost comparison and VfM achieved	**Financing cost**
Risk factors	1. Risk allocation 2. Risk transfer	**Retained risk cost value** **Premium cost**
Market capacity factors	1. Private sector interest Possibility of a competitive procurement process 2. Public sector capacity	

Existing Qualitative Criteria	Existing Qualitative Sub-Criteria	Existing Quantitative Criteria
Contract factors	1. Quantifiable contract performance output	**Ancillary cost**
Stakeholder engagement (Limited)	1. Collaboration with Stakeholders 2. Acceptability	

The most common project delivery models compared during the procurement process are traditional ones like Design-Bid-Build (DBB) and Design-Build (DB), along with construction period-only partnerships with private finance like Design-Build-and-Finance (DBF), versus long-term partnerships such as Public-Private Partnership (P3) models. Social infrastructure projects often use PPP (also referred to as P3) models like Design-Build-Finance-and-Maintain (DBFM), Design-Build-Finance-Maintain-and-Operate (DBFOM), and the P3 bundle model. Additionally, the progressive P3 model is emerging as a new procurement approach [10] [11] for social infrastructure projects, particularly for transit projects in Ontario.

1.2. Problem Statement

The procurement process of P3 model for the delivery of social infrastructure projects lacks a comprehensive approach aligned with Canada's commitment to sustainable development. There is a need to have a more relevant procurement process that is evolving with Canada’s objectives of sustainable development in the infrastructure sector and addressing transparency issues [11] impacting the P3 contract management process. The success of a P3 project goes beyond its financial considerations, challenging the traditional notion [12] [13]. Recent research on sustainable project management [14] suggests that achieving non-financial outcomes related to social and environmental issues is equally important for the overall success of construction projects during their management and delivery.

Neglecting these social and environmental considerations in evaluating P3 model limits the chance to improve community benefits relevant to different community members and groups including indigenous peoples, thereby increasing the likelihood of social disparities and community dissatisfaction [2] [15]. Additionally, issues with governance involving transparency, and ethics in managing social infrastructure projects have led to cost overruns and cases of corruption and fraud [16], together with the perceived lack of accountability as it operates under a consortium of private companies and the use of tight-schedule procurement process timeline [17] limit the community involvement and stakeholder engagement [18]. These examples highlight the need for adapting the existing procurement process for infrastructure projects specifically social infrastructure, which directly serves and engages the community. This adaptation is essential to ensure a more ethical and inclusive approach to delivering P3 projects in Canada.

Therefore, integrating environmental, social and governance factors into P3 assessments could lead to improved outcomes and value creation [19], a potential that has largely been overlooked. A procurement decision process that integrates qualitative ESG screening criteria is needed to evaluate not only financial aspects but also sustainable and ethical opportunities in project delivery models. This is particularly important to consider when screening a P3 model, which is commonly chosen for delivering social infrastructure projects in Canada.

1.3. Scope and Objectives

The main aim for this study is to integrate ESG criteria into the procurement process to align social infrastructure project with sustainable and responsible practices. The sub-objectives of the study are as follows:

1. Identify and describe ESG qualitative criteria for the procurement process of new social infrastructure projects.
2. Develop an ESG-PPP screening assessment matrix to evaluate the suitability of P3 models to deliver social infrastructure projects sustainably and responsibly.

3. Develop an Analytical Hierarchy Process (AHP)-PPP selection model to guide the selection of most suitable type of P3 model to deliver a given social infrastructure project.

By achieving these objectives, this study intends to provide useful knowledge for the current state of project delivery model selection, promote sustainable practices, and provide decision-makers an opportunity to prioritize non-financial aspects of a social infrastructure project.

1.4. Thesis Organization

This research comprises four chapters. Chapter two addresses current issues in social infrastructure projects, including project objectives, ESG procurement considerations, and P3 procurement models. Chapter three details how the matrix evaluates P3 model suitability for responsible sustainability and explains the AHP selection process steps in choosing a specific P3 model. Chapter four describe the practical application of the AHP-PPP selection model through case studies to assess its real-world effectiveness and reliability. Chapter five summarizes research findings on integrating ESG criteria into the screening matrix and selection model implementation. It explores implications and outlines recommendations for practical use and future research.

Chapter 2: Literature Review

2.1. Introduction

This chapter is comprised of five sections. The first section 2.2 will review the proposed social infrastructure projects, their characteristics, project drivers and challenges surrounding their proposed delivery in Canada. Following this, section 2.3 will explore various P3 models and the procurement process of P3 projects, as well as describe the project management and governance structure of the P3. Section 2.4. will review and identify the screening criteria required for sustainable and responsible project management of P3 projects. It will highlight existing state and key features of sustainable and responsible project management practices within the Canadian context. Finally, section 2.5 will summarise identified research gaps which will be addressed further in the methodology of this thesis.

2.2. Objectives of social infrastructure projects in Canada

The decision to select a specific delivery method is dependent upon the project's characteristics and objectives as well as its ability to deliver the project and other relevant considerations [20]. Thus, understanding the key objectives of the social infrastructure projects in Canada will provide a basis for the up-to-date evaluative criteria when deciding on a project delivery model. The following sub-sections of affordable housing, schools, hospital, public transit and recreation and culture facilities will provide an overview of the different types of social infrastructures, outlining their scope and commitment to addressing the various needs of Canadian communities.

2.2.1. Affordable housing in Canada

Affordable housing projects include planning, construction, renovation, or expansion works focused on providing affordable and subsidized housing options for the community. Social housing is a subset of affordable housing specifically addressing the needs of vulnerable low-income populations [21]. The driving factors for these projects include an increase in housing demand

due to a limited supply. Canada is currently implementing a range of housing projects to address the shortage of housing options, with the goal of providing sufficient availability of affordable housing by 2030 [22]. Most provinces are actively looking for proposals to enhance affordable housing options. They are particularly focusing on creating sustainable and cost-effective housing developments as outlined in their infrastructure plans [23] [24].

Ontario is currently developing proposals to integrate housing with public transit infrastructure. These housing complexes will include commercial and communal spaces, strategically positioned around its four main transit subways, forming what is known as a transit-oriented development [25]. British Columbia is actively involved in developing several affordable housing infrastructure projects under its homes for people action plan. This plan targets the increasing demand for affordable housing among Indigenous peoples, the elderly, students, families, and individuals affected by domestic violence [26]. Saskatchewan intends to build, rehabilitate, and adapt existing social housing, and make community housing more sustainable [27]. Likewise, other provinces including Quebec, Alberta, Manitoba, and the Atlantic provinces are proposing similar approaches to address the housing scarcity and achieve Canada's objective of providing affordable housing by 2030**.**

The Canadian housing sector's main goal is to offer a variety of housing options that are sustainable, affordable, and quickly built, while addressing social inequalities among various community groups. However, delivering these large-scale housing projects which involves various stakeholders will pose challenges, such as a tight schedule and community opposition. Table 2 below summarises the key objectives for social housing in Canada and the ESG issues to consider.

Table 2. Key objectives for Social Housing in Canada.

Existing project drivers	Environment, Social and Governance issues to consider
Schedule: Of fast-track nature	Social: Fast-track projects may limit the engagement of a broader range of local community groups, potentially resulting in disruptions and conflicts if community concerns are not properly addressed.
Scope/Scale: Mix housing options and complexes	Environmental: Large-scale projects may have significant environmental impacts, such as habitat destruction or increased energy consumption.
Diverse stakeholders/ Community engagement	Social: Effective community engagement can address social acceptance issues and ensure that the project benefits all stakeholders, including marginalized communities. Governance: Involving diverse stakeholders enhances transparency and accountability in project decision-making processes, promoting good governance practices.
Potential risk:	Community Risks: ▪ Challenges related to social acceptance, such as social exclusion and housing inequities [28], ▪ Changes in neighborhood dynamics including concerns related to traffic, or changes in neighborhood character [29]. Leading to impact on the marketability of housing projects.

2.2.1.1. Schools

School infrastructure projects include planning, construction, renovation, or expansion works focused on educational facilities. New educational facilities are built to accommodate growing student populations, replace outdated facilities, and meet specific educational requirements. The objectives of these projects include providing conducive and innovative learning environments that cater to the evolving needs of students [30], community development, and the achievement of broader societal sustainable development goals. In Alberta, similar to other provinces, the driving factors of school projects are the condition of existing school buildings, the well-being and safety of students, and enrollment trend [31]. Provincial governments are focused on building, renovating, and expanding schools to ensure equal opportunities for students and support community growth and educational excellence [22] [32] .

Likewise, there is a significant demand for building, repairing, and maintaining schools on reserve land [33]. Fostering partnerships and collaborative decision-making with Indigenous communities and tribal councils during school projects is crucial for providing culturally relevant facilities, advancing the quality of life for Indigenous people, and ensuring transparency and accountability in project planning and implementation.

During the operation of school buildings, various school programs promote sustainability practices during operation of schools, with some specifically evaluating energy and water use efficiency, waste, and green gas emission of the buildings [34]. A report highlights that schools with effective maintenance management practices achieve higher energy efficiency levels [35]. Therefore, incorporating feedback loops into a school project delivery model allows data collected from assessing waste, energy, and water efficiency in existing school buildings to inform the design and construction of new school infrastructure. Table 3 below summarises the key objectives for schools in Canada and the ESG issues to consider.

Table 3. Key objectives for Schools in Canada.

Existing project drivers	Environment, Social and Governance issues to consider
Enrollment Trends, Educational Needs and Innovation	Environmental: Use of innovative construction techniques expertise in the school design and construction to cater to diverse student needs. Governance: Effective coordination among stakeholders to address educational needs efficiently and transparently.
Indigenous needs	Environmental: Respect for Indigenous lands and ecosystems, ensuring construction activities do not disrupt sacred sites or natural habitats [36]. Social: Respect for Indigenous rights and cultures, involving Indigenous communities in decision-making processes regarding indigenous school project implementation. Governance: Establishing partnerships and agreements with Indigenous communities to ensure their voices are heard and their needs are addressed throughout the project lifecycle [37].

Existing project drivers	Environment, Social and Governance issues to consider
Operation efficiency data and stakeholder involvement	Environmental: Efficient operation and maintenance practices to minimize resource consumption and environmental impacts. Social: Involvement of stakeholders such as school boards, parents, and teachers in decision-making processes related to operation and maintenance [38]. Governance: Establishing stakeholder engagement and feedback collection to improve operational efficiency and address concerns quickly
Potential Risk	Operational risks: ▪ Challenges may arise during the maintenance and operation of P3 school projects. As some private project companies may not involve the school boards, parents, teachers, and other relevant stakeholders and their control may pose operational and maintenance restrictions [38].

2.2.1.2. Hospitals

Hospital infrastructure projects include planning, designing, constructing, renovating, expanding, or development works that aim to build or improve healthcare facilities. The new hospital structures are built to accommodate growing healthcare needs, population increases, and replace outdated facilities. The main drivers for these projects include healthcare demands, medical technology advancements, and community health priorities. Also, the growing population and indigenous communities play a key role driving the decision-making process for hospital projects, particularly post-COVID-19 [39]. Hence, it is important to build hospital infrastructure and expand service capacity to enhance healthcare accessibility and meet the growing healthcare demands.

Although the positive objectives of these projects are evident, Canadian hospitals are recognized for their significant environmental impact, mainly attributed to the continuous and essential 24/7 healthcare services they provide. They greatly contribute to a significant environmental impact by generating waste, consuming energy, and depleting resources [40]. Because of this, projects involving hospitals need to go through a thorough planning and design

process, with an emphasis on being environmentally friendly. The primary objective for upcoming projects is to construct hospital infrastructure that not only addresses present community healthcare requirements but also prioritizes long-term environmental sustainability by incorporating eco-friendly practices throughout the entire project lifecycle.

Likewise, hospitals are typically built to last 30-40 years, are struggling with delayed maintenance in Canada [41]. Essential renovations are being postponed due to funding shortages in the public sector [42]. In order to address this problem, it is important to integrate maintenance and operations planning into the design and delivery of new hospital facilities. Additionally, involving maintenance personnel is valuable as they can share their expertise on the functioning of existing projects, pinpointing areas for improvement and helping avoid potential issues [43]. Table 4 below summarises the key objectives for hospitals in Canada and the ESG issues to consider.

Table 4. Key objectives for Hospitals in Canada.

Existing project drivers	Environment, Social and Governance issues to consider
Scope/Scale: New construction of specialised facilities	Environmental impact concerns: Consider involving private sector expertise and innovation in green building processes and technologies. Addressing concerns regarding the hospital project's overall environmental footprint, including energy consumption, waste generation, and carbon emissions. Social: Consider the community's response to the construction of a new specialized facilities, including disruption to local businesses or residents.
Funding: Budget constraints and value-for-money	Governance: Ensure transparency and accountability in budget allocation and expenditure and possibility of early contractor involvement, particularly regarding environmental and social cost management.
Operational efficiency: Environmental operation footprint	Environmental: Long-term sustainable practices in the operation of specialized facilities.

Existing project drivers	Environment, Social and Governance issues to consider
Stakeholder Involvement: Navigate the complexity of stakeholders and gathering diverse input	Social: Facilitating meaningful participation from diverse stakeholders, including local residents, environmental advocacy groups, and regulatory agencies in discussions about environmental concerns and potential mitigation strategies.
Potential risk	Environmental Risks: ▪ Contamination issues, Ecological considerations, Environmental impact concerns including challenges relating to adopting green building process [44]

2.2.1.3. Public Transit

Public transit infrastructure projects involve planning, designing, constructing, renovating, expanding, or developing facilities that support and enhance public transportation services within a provincial city. These include stations, rail systems (like metros or subways), and bus rapid transit lanes [45]. They serve an important role in shaping the efficiency, accessibility, and sustainability of public transportation systems, contributing to the overall mobility and livability of urban areas [46]. The factors driving these projects include changes in transportation needs, population growth, technological advancements, and government priorities. Canada is dedicated to creating healthier, sustainable transit and increasing public transportation usage for their daily commutes [46] [47]. However, these projects necessitate substantial financial commitment and coordination. Currently, they face an operational funding shortage, putting their ability to effectively serve communities at risk [48]. Likewise, specific projects, such as Ottawa's Light Rapid Transit, Edmonton's Light Rapid Transit line, and Toronto's Eglinton Crosstown LRT line, encountered setbacks, prolonged schedules, and budget overruns during its construction, primarily due to funding-related challenges [47]. Subsequently, securing lifecycle reliable and sustained lifecycle funding is an important consideration for the successful delivery and completion of public transit projects.

On the other hand, equity-deserving groups, such as racialized people, Indigenous communities, persons with disabilities, newcomers, seniors, low-income individuals, and people

experiencing homelessness, are recognized as the primary users of public transit [47]. To guarantee effective solutions that meet their community transit needs, it is important to acknowledge and address the social and environmental challenges faced by these community groups early on, during the planning and implementation phases. Similarly, improved collaboration and communication among different levels of government is important. Implementing a transparent decision-making process grounded in evidence is vital for the development and delivery of transit projects, aiming to improve project governance [49]. Table 5 below summarises the key objectives for public transit in Canada and the ESG issues to consider.

Table 5. Key objectives for public transit in Canada

Existing project drivers	Environment, Social and Governance issues to consider
Scope/ Scale: Deliver diverse range of transit options.	Social: Disruption to local communities and displacement of residents due to construction and transit infrastructure expansion.
Operational funding: Reliable and sustained lifecycle funding	Environmental/Social: Green funding sources to support ongoing operations and maintenance. Green funding refers to financial mechanisms specifically designed to support projects that have positive environmental impacts or contribute to sustainability goals [50].
Community engagement: Transparency, coordination, and evidence-based decision making	Social: Promoting inclusivity and addressing the needs of marginalized communities in transit planning and implementation.
Potential Risk	Operational and Maintenance Challenges: ▪ Delays, reduced scope, or project abandonment due to funding shortages. Also, delivered transit options overestimation or underestimation of future ridership, impacting revenue and financial sustainability for the project.

2.2.1.4. Recreation and Culture infrastructure

Recreation infrastructure projects involve planning, designing, constructing, renovating, expanding, or developing facilities and spaces that support and facilitate recreational activities and leisure pursuits. These infrastructures include museums, indigenous heritage centers, sports, and aquatic facilities and other indoor and outdoor recreational community centres [2] [51] . They serve

an important role in advancing Canada's social-cultural objectives to provide diverse opportunities for individuals of all ages and abilities to engage in leisure activities, promote community well-being, and create a sense of place and belonging. Delivering these projects necessitates addressing diverse demographic needs in a community [52].

Likewise, with the growing number of immigrants and increasing ethnocultural diversity in various communities, a key challenge identified in the delivery of culture and recreation infrastructure in Canada is the rise of changing cultural practices [53]. This poses a great risk of project acceptability. Addressing this challenge involves anticipating future changes in culture, demographics, and the economy, emphasizing the need for a forward-looking approach in the planning and delivery of culture and recreation infrastructures. On the other hand, Insufficient funding for maintenance and operation by the municipality poses challenges, impacting the sustainability and longevity of the facilities [53]. Table 6 below summarises the key objectives for recreation and culture in Canada and the ESG issues to consider.

Table 6. Key objectives for recreation and culture in Canada

Existing project drivers	Environment, Social and Governance issues to consider
Stakeholder diversity: Transparency and inclusivity	Governance: Ensuring all stakeholders are engaged throughout the project lifecycle, with transparent communication and decision-making processes.
Post Construction Phase: Maintenance consideration	Environment: Considering the long-term sustainability of maintenance practices to ensure environmentally safe and long-lasting infrastructure assets.
Potential Risk	Community Opposition: ▪ Resistance or opposition from the community due to concerns over project impact, design, or perceived lack of consultation

In summary, new social infrastructure projects phases need to be carefully coordinated to tackle identified ESG considerations and potential risk in delivering sustainable infrastructure project outcomes. Each project phase must address environmental responsibility, social equity, and transparent decision-making for the community. These considerations will influence how the

project is planned, designed, and managed [54] [55]. Currently Canada plans, designs, and manages social infrastructure projects using either a traditional procurement, where the government fully funds projects internally or a P3 procurement, which involves the private sector participating in funding and delivering the project [56]. Table 7 below shows the different categorises of PDM used in Canada for social infrastructures.

Table 7. Category of PDM used in Canada for social infrastructures

Category of PDM used in Canada for social infrastructures	PDM Types
Sequential model	Design-Bid-Build (DBB)
Overlap models	Design-Build (DB),
	Design-Build-Finance (DBF)
Innovative models	P3 – DBFM, DBFOM
	P3 Bundle
Collaborative models	IPD/ Alliance
	“Progressive” P3

2.3. Public-private partnership models in Canada

P3s are collaborative arrangements between the private sector and government to manage various phases of an infrastructure project, including design, construction, funding, oversight, and maintenance. These projects phases are consolidated into a single contract, spanning 25 to 30 years [57], comprising the core services to be delivered by the private sector [58]. The typical structure of a P3 model in Canada constitutes two main parties; the government who is the owner and the project consortium which is comprised of number of stakeholders acting as one private entity [56] as seen in Figure 3 below. Likewise, Figure 4 below shows the basis for the variation of the P3 models in Canada; it visualizes how traditional and P3 models vary in terms of private sector involvement and risk transfer. The PDM situated towards the upper right involve significant private sector participation and more-risk transfer, while those towards the lower left represent PDM with lower private sector involvement and less risk transfer [57]. Table 8 below outlines the main characteristics of P3 models in relation to their scope of core and non-core services.

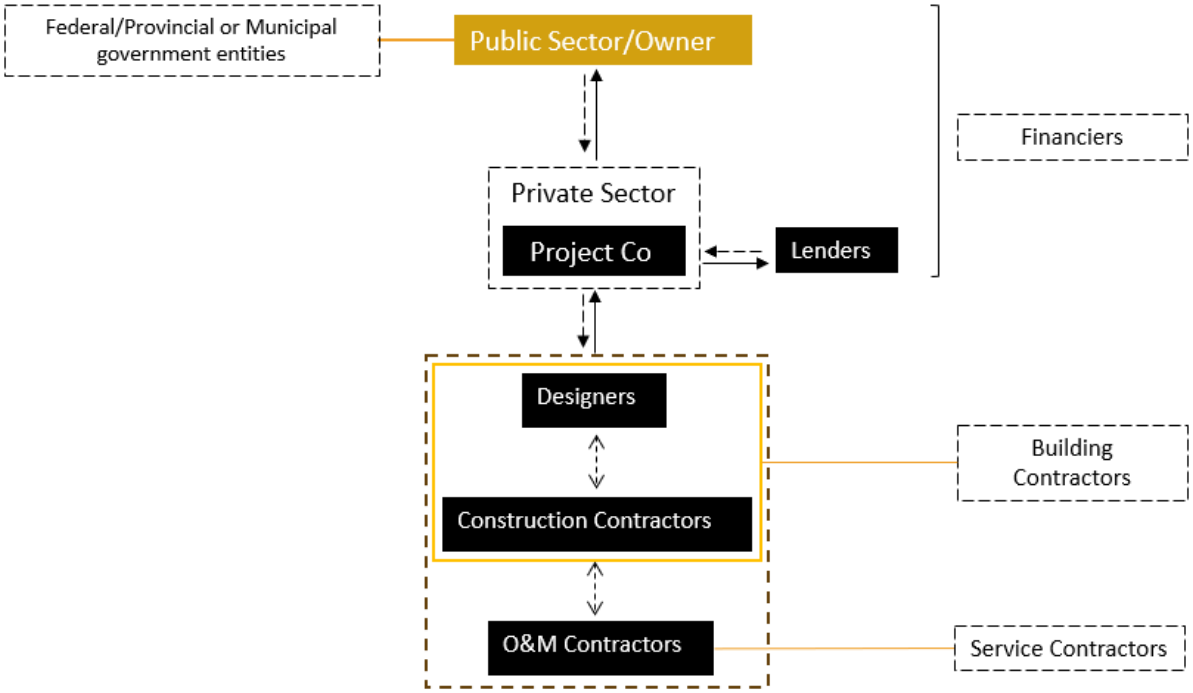


Figure 3. Partnership Structure in a Typical P3 Model in Canada

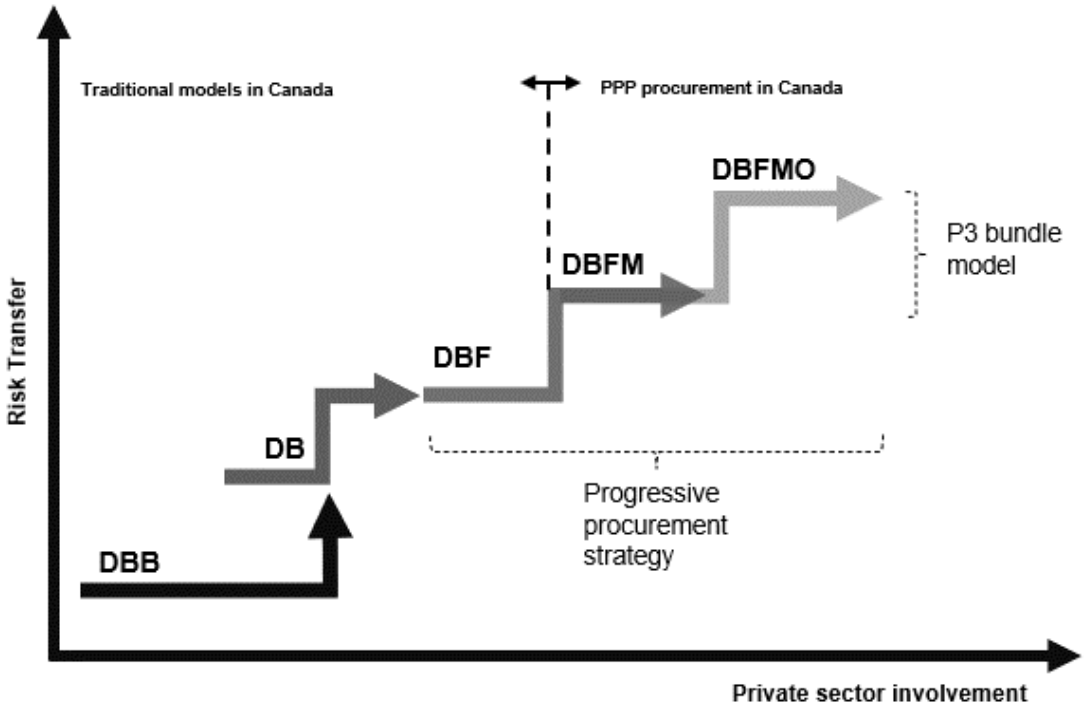


Figure 4. Traditional PDM and P3 models in Canada, adapted from *[57]*.

Table 8. Types of P3 models in Canada

Type of P3 model	Core Services	Non-Core services (supportive of the core services)
DBFM	Focuses on design, construction, financing, and maintenance aspects.	1. Cleaning and janitorial services 2. Security services 3. Landscaping and grounds maintenance 4. Waste management and recycling 5. Catering and food services 6. Facility management and building maintenance 7. IT support and helpdesk services 8. Administrative and clerical support 9. Transportation and shuttle services 10. Event planning and coordination
DBFOM	Extends beyond maintenance to operational aspects.	
P3 bundle model	Involves bundling smaller scale projects into one large project	
Progressive P3 model	Engaging private stakeholders, including contractors, at an early stage to collaboratively define project specifications and pricing before finalizing the project contract [59].	

Non-core services may be required throughout various stages of the project lifecycle, including during construction, operation, and maintenance phases. However, they are typically provided on an ongoing basis to ensure the smooth functioning and upkeep of the project's facilities or operations [58] [60].

Different provinces use different P3 models for certain social infrastructure projects. In Ontario, the DBFM model has been extensively procured for most of the hospital projects currently in their operational phase [61], as depicted in the Figure 5 below. Additionally, a new model called the progressive P3 model was introduced in 2021, which has been predominantly involved in recent transit projects in the province. Unlike traditional P3 models, the progressive P3 model involves private stakeholders in the early planning phases of the project before finalizing the draft project agreement [59]. This approach enables a collaborative review of project objectives and risk factors, ensuring a shared understanding among stakeholders [10].

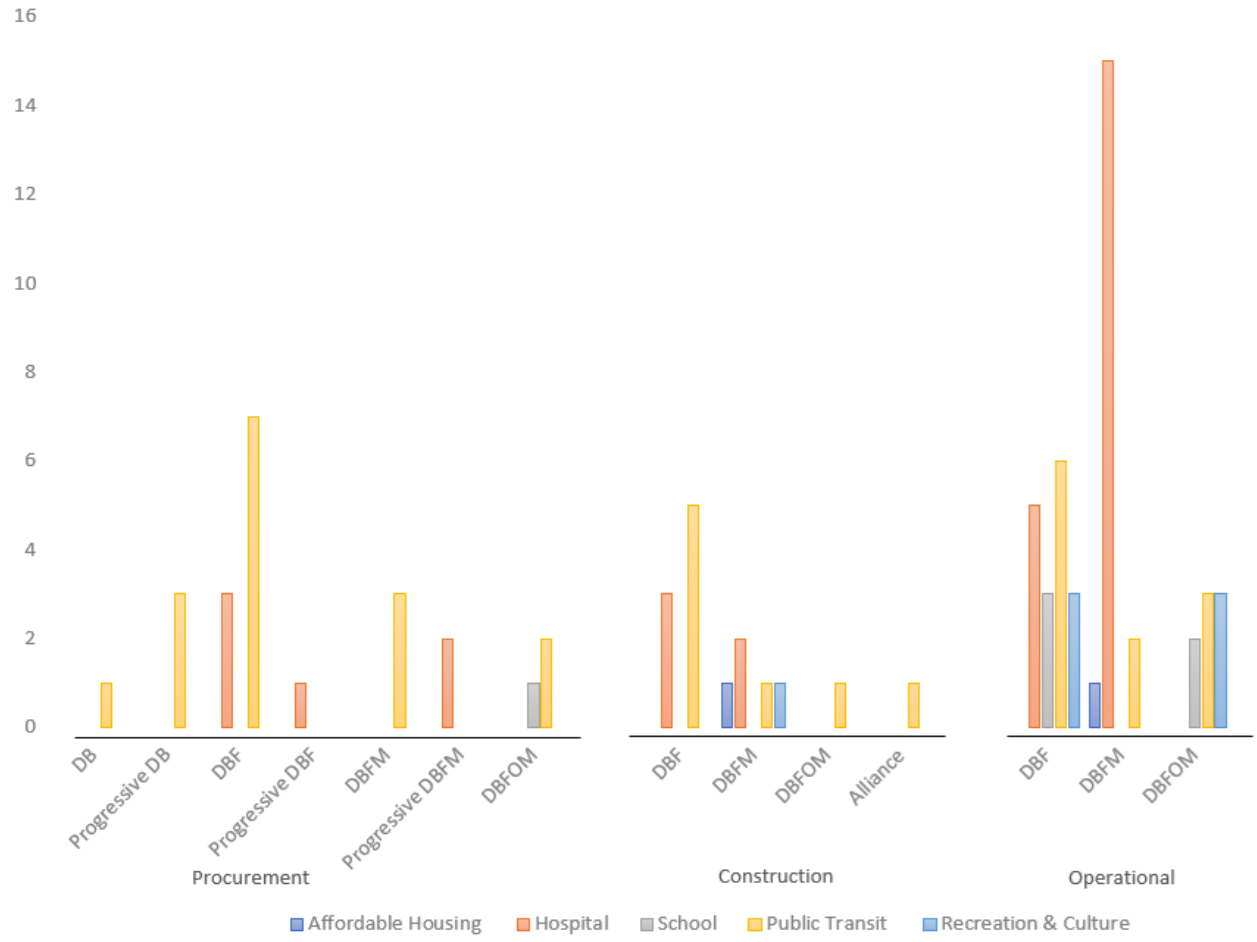


Figure 5. Ontario's P3 models across Different Social Infrastructure Projects

In Alberta and Saskatchewan, a variation of the P3 model known as the P3 Bundle is used for constructing schools, as depicted in Figure 6 and 7 below. The Alberta schools' phase 1,2,3 has been delivered using a single bundled DBFM contract, with maintenance periods extending until 2040, 2042, and 2044 respectively [62]. Likewise, the Saskatchewan joint use school projects were constructed using a 32-year bundled DBFM model with maintenance periods extending to 2045 [63]. However, concerns have been raised about the suitability of the DBFM P3 model for these projects. In Alberta, criticism is focused on limited school administration control and delays in addressing maintenance issues [64]. Similarly, in Saskatchewan, the school projects have faced criticism for significantly higher maintenance costs compared to older non-P3 school projects [65]. Other provinces like Quebec, British Columbia, and New Brunswick primarily use P3 models for

hospitals as seen in Figure 8 below, and provinces like Yukon and Prince Edward Island do not have any presence of P3 social infrastructure projects, as seen in Figure 9 below.

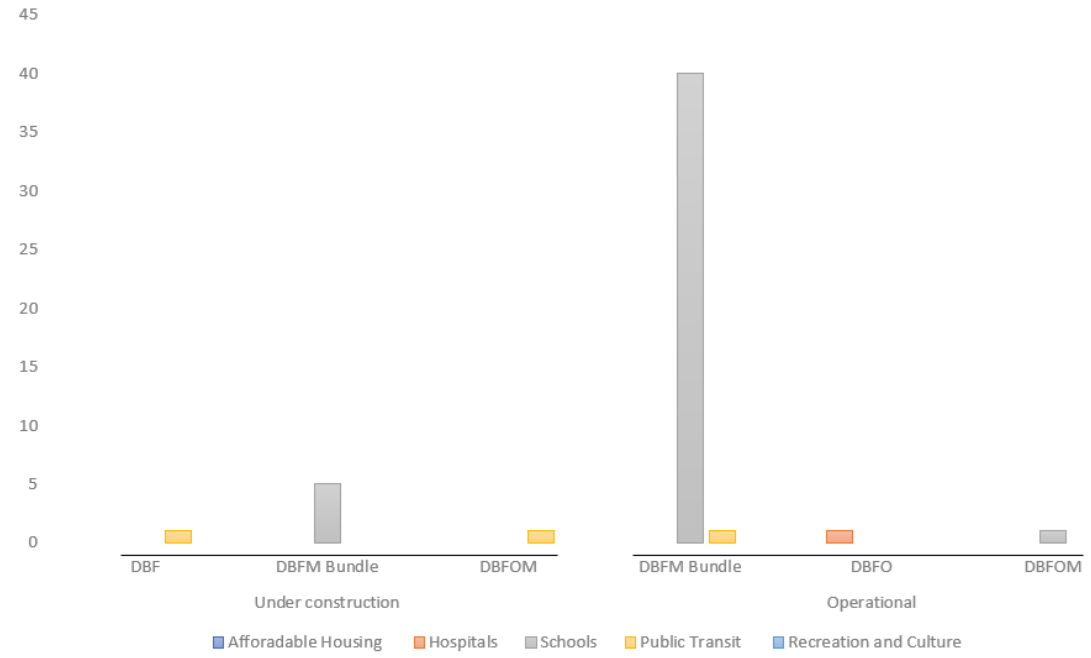


Figure 6. Alberta's P3 models across Different Social Infrastructure Projects

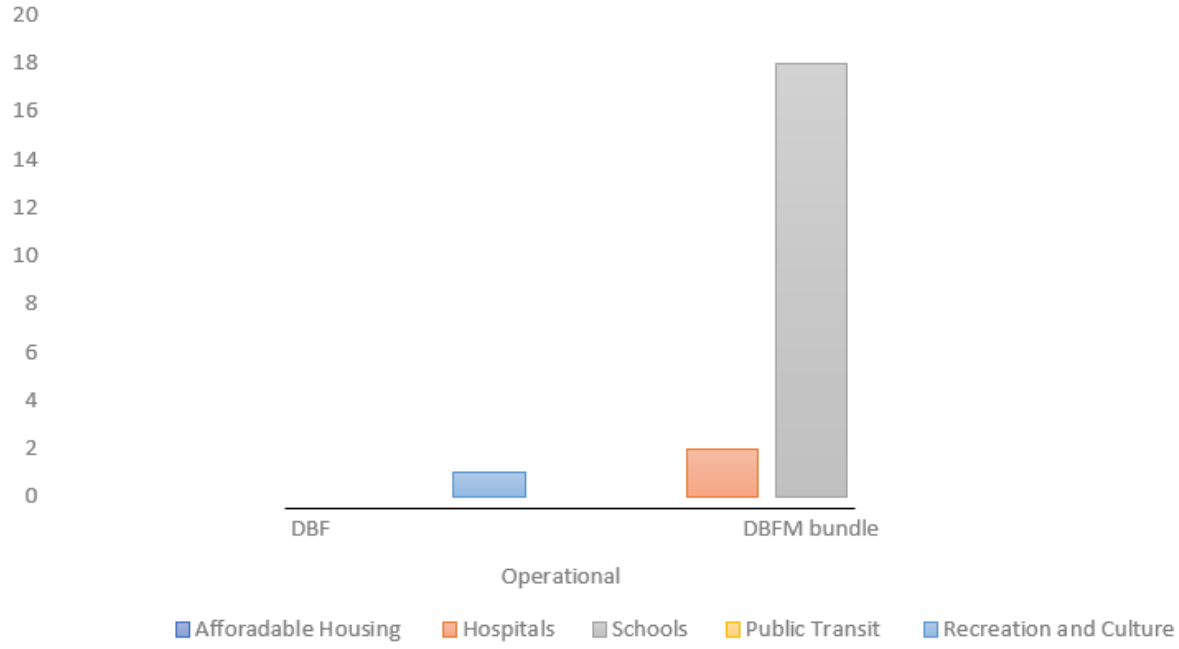


Figure 7. Saskatchewan's P3 models across Different Social Infrastructure Projects

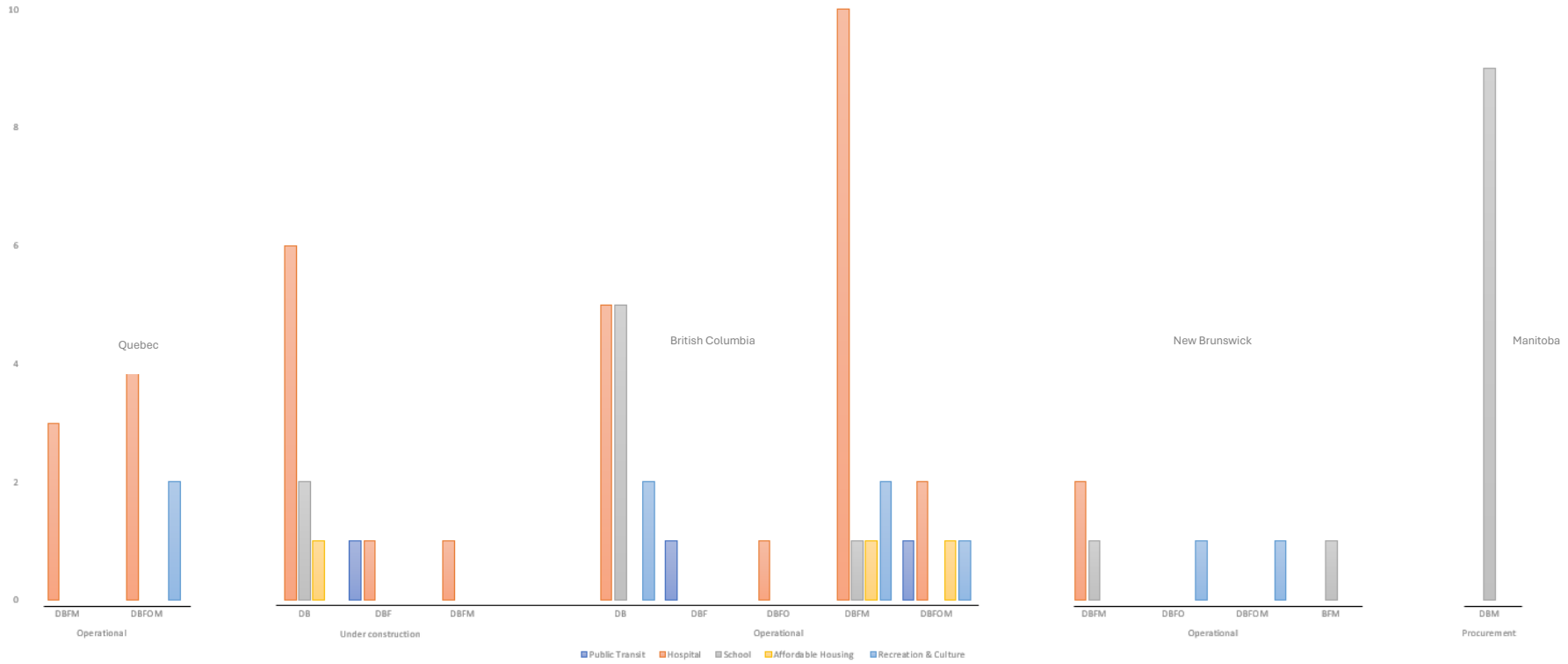


Figure 8. P3 models across different Social Infrastructure Projects: Québec, British Columbia, New Brunswick, and Manitoba *[9]*

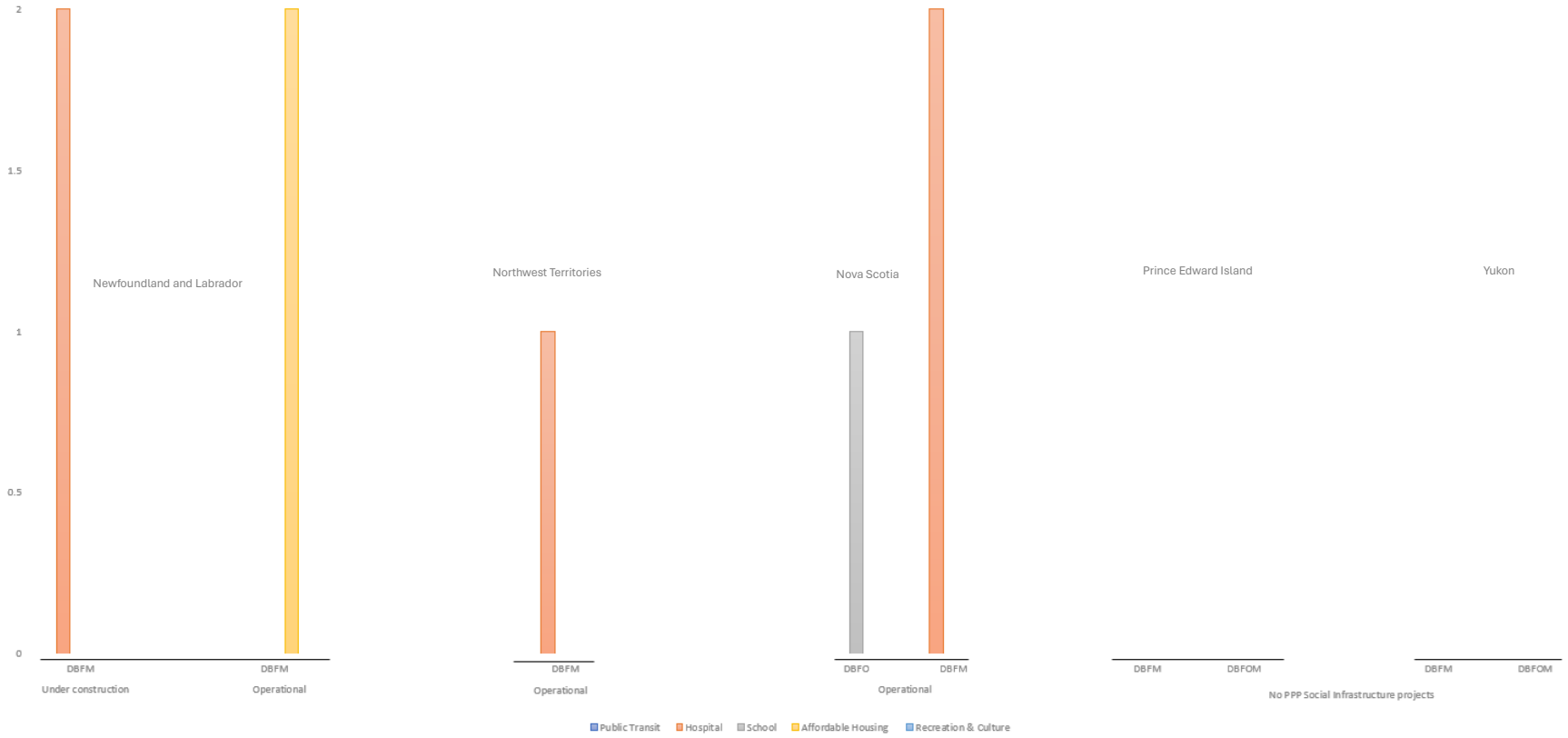


Figure 9. P3 models across Different Social Infrastructure Projects: NL, Nova Scotia, PEI, and Yukon *[9]*

2.3.1. Procurement of a P3 model for social infrastructure in Canada

The procurement of PDMs occurs during the project's planning phase, as shown in Figure 10 below. It begins with identifying and reviewing project scope elements, key project risks, and available PDM options. Afterward, procurement objectives are established along with a set of defined criteria to guide the evaluation of the most suitable procurement options for project delivery. A thorough qualitative assessment is then conducted to rank the available procurement options based on these established criteria [66]. This qualitative stage results in a shortlisted set of PDMs and involves evaluating the potential for the project to be procured as a PPP. After, a second stage involves quantitative analysis, also known as VfM compares the shortlisted PPP model with the traditional PDM option. It calculates the risk-adjusted project costs to compare financial advantages expressed as cost savings benefits [54]. Figure 11 below illustrates these stages in the P3 procurement process. If the value for money is negative for the PPP model, a review of the qualitative analysis results is conducted, and consideration is given to procuring a non-PPP model as seen Figure 12 below. Thus, it is important to recognise that while P3s may be suitable for numerous project scenarios, they may not always be the most suitable option for small project sizes with no significant risk to the public sector [67] [58].

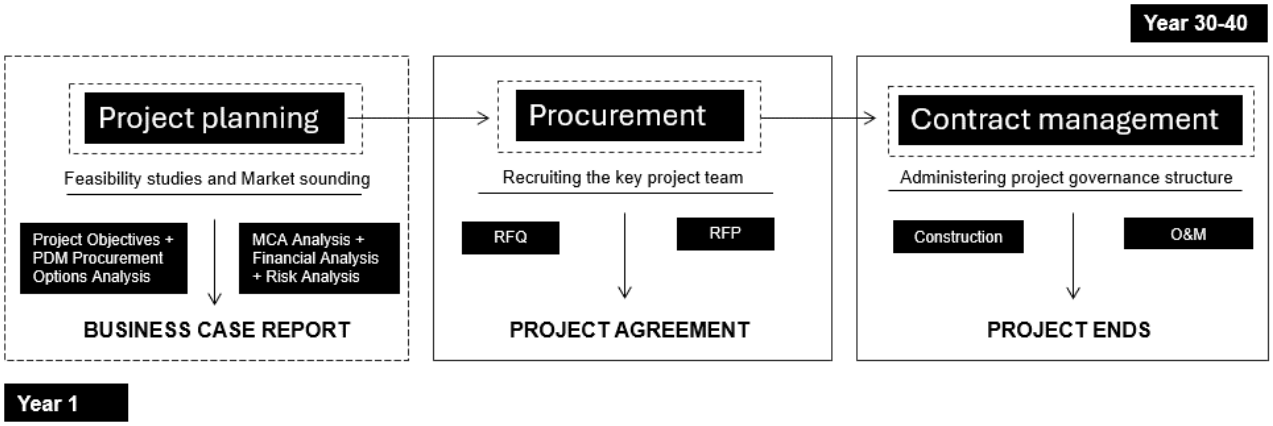


Figure 10. Procurement Phases of a Social Infrastructure P3 Model in Canada

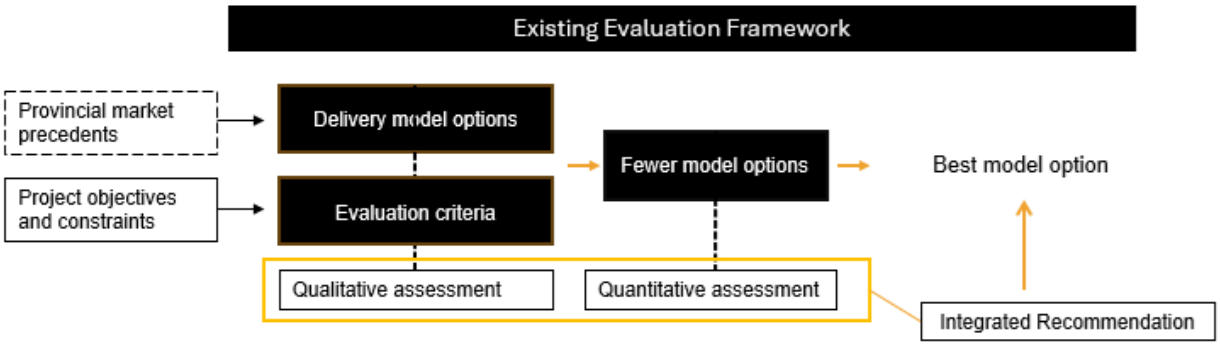


Figure 11. The Two-Stage Procurement Process of a P3 Model in Canada

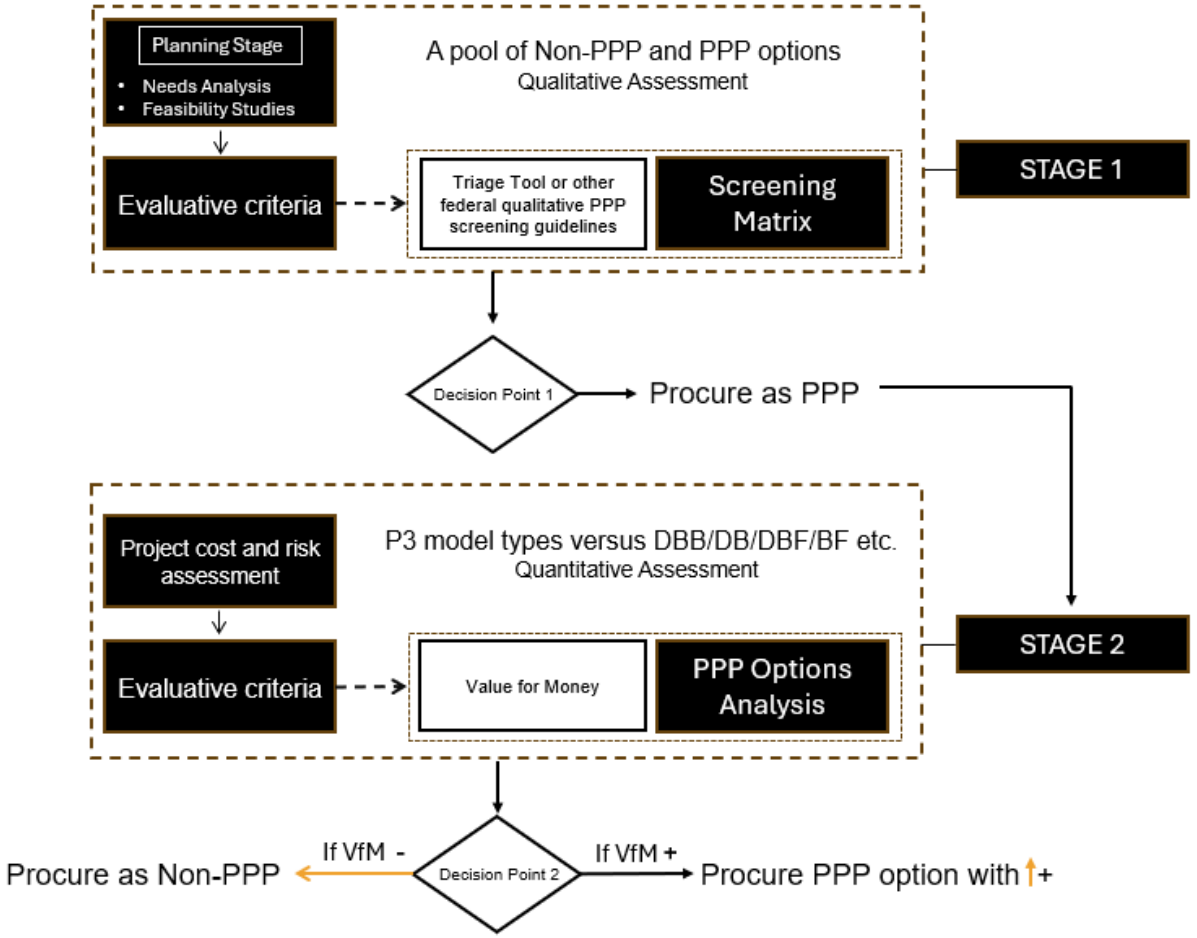


Figure 12. Existing evaluation framework for assessing P3 model potential in Canada *[68]*

The qualitative assessment relies on guidelines provided by P3 Canada and a Triage tool from PWGSC's Strategic Sourcing Sector in 2021 [68] [56] [69] to develop qualitative screening matrices. These guidelines provide a systematic process for screening infrastructure projects for P3 potential. Provinces across Canada customize qualitative assessment matrices to align with their infrastructure needs and provincial government priorities when evaluating the suitability of a P3 model for infrastructure procurement. These matrices incorporate various evaluative criteria, including private sector interest, project characteristics, risk transfer opportunities, innovation, and financial considerations [56] [70]. However, the decision to pursue P3s is guided by shared specific circumstances and objectives across provinces. Existing factors such as project size, complexity, risk, and funding availability are significant influencers in the procurement decision-making process. This study has compiled common key scenarios and identified thresholds across provinces like Ontario, Alberta, British Columbia, Quebec, and Saskatchewan regarding the use of P3s for social infrastructure projects described in Table 9 and illustrated in Figure 13 below, providing an understanding of the existing key assessment criteria under which provinces in Canada have considered the P3 model for social infrastructure project procurement. However, these considerations often overlook important environmental, social, and governance factors, which are important for assessing the sustainability and responsible performance of P3 projects. Neglecting these aspects may result in an incomplete evaluation of the project's full value, including its impact on people and the environment [71] [72].

Table 9. Common Factors and Key Thresholds for Considering P3s in Canadian Provinces

Project Criteria	Alberta, British Columbia, Ontario, Quebec,	Saskatchewan
Project size	Project size exceeding 100 million [73] [74] [75]	Projects with a capital cost of $50 million or more may undergo screening for potential P3 viability, provided there is an inclusion of maintenance and/or operations components and has significant risk [76]

Project Criteria	Alberta, British Columbia, Ontario, Quebec, Saskatchewan
Value for Money	When positive VfM is achieved by evaluating both quantitative and qualitative benefits. The lowest bid may not win if it does not offer adequate value for money. If the VfM exceeds 3%, P3 consideration is pursued. However, if it falls below this threshold, a sensitivity analysis is conducted to determine the feasibility of a P3 model [76]
Competitive and Fair Procurement Process	Availability of three project consortiums to bid for a project [77]. This has been a rising challenge as risk uncertainties to the private sector has limited the bidding pool for P3 model procurement [78].
Innovative Design Delivery and Risk Allocation	Most social infrastructure projects with complex designs and technology integration opted to screen the projects for P3 procurement to gain benefits of cost savings from innovative solutions and risk transfer provided by P3 partners [79]

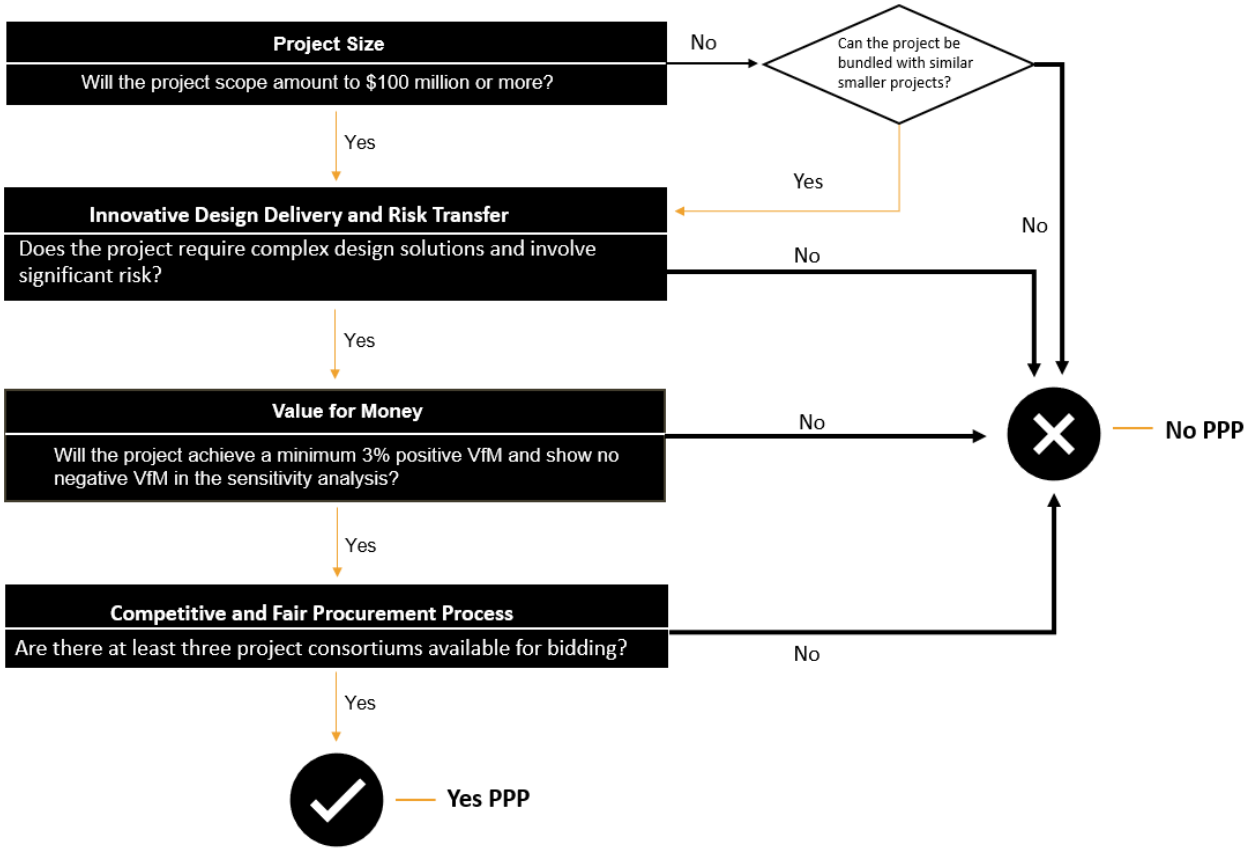


Figure 13 Existing P3 Decision Flow Chart for Social Infrastructure Projects in Canada

Various VfM reports highlights differing cost-saving benefits across different P3 models [80]. While reports for models like DBFM and DBFOM typically range from 15% to 22% [81], VfM assessments for progressive P3 models are currently unavailable due to limited projects reaching financial close. However, early stakeholder engagement in progressive models is expected to enhance VfM considerations [11]. This proactive approach allows for the early identification of factors impacting financial implications and broadens the scope of VfM scenarios. This timely stakeholder involvement in the planning process has the potential to enhance project accountability, transparency, and performance expectations. Purposely, this could improve overall contract integrity and facilitate efficient P3 project governance [70].

2.3.2. PPP project governance in Canada

Governance is defined as a structured system of decision making that ensures effective coordination, accountability, and transparency throughout the project lifecycle [82]. This ensures successful delivery of project objectives and meets stakeholder interests [83]. When decision-making lacks transparency, it often results in cost overruns and budgeting discrepancies. Similarly, weak governance structures can contribute to a lack of accountability, which hinders the timely identification and resolution of issues [82]. As a result, this can lead to delays and failures in delivering infrastructure projects. The P3 governance structure includes the organizational framework established to oversee and manage a P3 project. It outlines the roles, responsibilities, and decision-making processes of each stakeholder involved, including government agencies, private sector partners, and possibly other entities such as regulatory bodies or community council representatives [84]. Different governance structures comprise different project governance mechanisms. Governance mechanisms refer to the different undertakings within the organizational framework put in place to oversee and manage projects effectively. They include frameworks for decision-making, roles and responsibilities of project stakeholders, communication channels, risk management procedures, and performance monitoring schedules [85]. Canada’s

P3 governance structure integrates four governance mechanisms, as described in Table 10 below, to ensure that the P3 projects are executed according to established objectives, schedules, and budgets, while also addressing any potential risks or issues that may arise during project implementation.

Table 10. Government Mechanisms and Considerations in Canadian PPPs

Governance mechanisms type	Scope of definition	Governance mechanisms used (Formal)
Contractual governance	This is a legal agreement which defines the rights, responsibilities, and obligations of each party, as well as the terms and conditions between the public and private sectors involved in a P3 project.	• P3 project agreement adhering to the IPFP Framework – Ontario [86] • P3 project agreement including a Tri-party agreement – Alberta School projects [87] • Lenders' Direct Agreement • Independent Certifier Agreement
Relational governance	This mechanism focuses on the interpersonal relationships, communication channels, and collaboration frameworks established between the public and private sectors, and the community. It aims to foster trust, cooperation, and mutual understanding among project stakeholders to ensure effective project delivery. It may involve informal processes, such as meetings, negotiations, and relationship-building activities, as well as collaborative problem-solving in response to unexpected occurrences [88].	• Community Benefits Framework – Community benefits agreement • Community Engagement and Stakeholder Relations Plan [86]

Governance mechanisms type	Scope of definition	Governance mechanisms used (Formal)
Risk governance	This mechanism is designed to identify, assess, mitigate, and manage risks associated with P3 projects. It includes strategies on identification of partnership risks, procedures to communicate identified risks, and decision-making steps to minimize potential negative impacts on project outcomes.	Risk identification and resolution clauses in project agreement contract forms [86]: • Proceeding at Risk Matters and Notice • Dispute resolution procedure • Force majeure
Reporting governance	This mechanism refers to the structured process by which information is collected, documented, analyzed, and communicated within a project. It ensures reporting on progress, achievements, and challenges of the project, facilitating effective communication.	A tracking and reporting system to demonstrate the progress of: • The Community Benefits and Liaison Plan • Construction Progress Schedules • Financial performance and cost budgets including change orders. • Quality management and the Monthly Performance Monitoring Reports in adherence to the performance monitoring program – Ontario [86] • Energy performance monitoring
Environmental governance	This mechanism refers to the process involving setting standards and requirements to protect and preserve the environment. It helps regulate environmental issues by promoting sustainable practices and reducing environmental risks and impacts of a P3 project.	• LEED Rating • Toronto Green Standard Design and Construction Obligations [86]

As seen in Table 10 above, the P3 project agreement is a contract governance mechanism that ensures effective management [89]. In Canada, the project agreement also provides and describes the undertakings of relational, risk, and reporting governance mechanisms. The CCDC

(Canadian Construction Documents Committee) contract forms are widely acknowledged and adopted as the standard references for governance frameworks used in the execution of large-scale social infrastructure projects. Most social infrastructure projects in Canada are governed by either a CCDC 2 for Design-bid-build delivery or CCDC 14 for Design-build or P3 project delivery. These contract forms are highly regarded for their perceived objectiveness and fairness in ensuring effective project delivery [70] [90]. However, reports of transparency issues and corruption in P3 social infrastructure projects [16] indicate a lack of emphasis on fulfilling the contract roles with accountability. Thus, to mitigate these transparency and accountability issues, monitoring and evaluating stakeholder management is essential.

Relational governance involves stakeholder management in the organizational framework. During the planning and procurement stage, the P3 project team is formed, often including third-party advisors [57] [91]. In Canada, common advisors for P3 projects typically include legal, technical, and financial experts. However, it remains uncertain whether environmental and social advisors are deemed essential as part of the technical advisory team. The environmental and social advisors may play an important role in P3 project implementation for several reasons as firstly, they ensure compliance with environmental regulations and social responsibilities, minimizing negative impacts on the environment and communities. Their expertise helps identify potential environmental risks and social concerns early in the project lifecycle, allowing for mitigation measures. Additionally, environmental and social advisors contribute to stakeholder engagement efforts, facilitating communication with local communities and addressing their concerns [92]. Overall, their involvement for relation governance promotes sustainable development, enhances project credibility, and reduces the risk of delays or conflicts arising from environmental or social issues [92]. Hence, understanding stakeholder changing aspects in P3 projects is important for sustainable development and project success [93]. Figure 14 below illustrates the key stakeholders that form the key components of a relation governance structure

in Canada. The community stakeholders ar among the key stakeholders that have an impact to P3 projects and are broadly impacted by the P3 project [92].

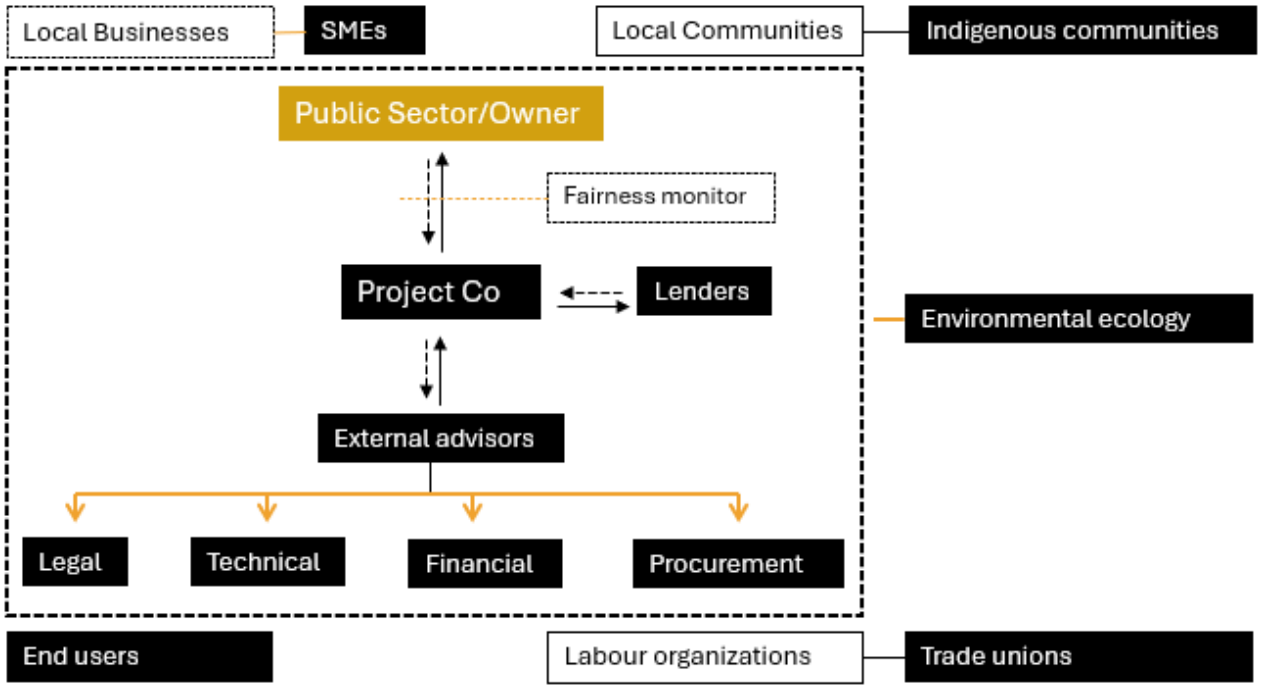


Figure 14. Stakeholder Structure in P3s in Canada *[57]*

Public Community Benefits Agreement (CBA) have been employed to ensure effective relation governance of community stakeholders in P3 projects. A CBA is a is a contractual agreement that specifies and upholds the advantages that a community gains from a specific infrastructure or development project. It particularly focuses on marginalized groups vulnerable to social exclusion, discrimination, poverty, and violence, ensuring their inclusion and well-being within the project's benefits. These marginalized groups include recent immigrants, persons with disabilities, women, veterans, youth, Indigenous peoples, and local social trade enterprises. The CBA aims to establish fundamental standards for offering employment, training, and community supply chain opportunities to marginalized groups [94]. Despite their potential, public CBAs have been underutilized in social infrastructure projects within P3s,particularly for hospitals as illustrated in Figure 15 below [94] [95]. However, with Canada's commitment to fostering more benefits to

inclusive communities through the Investing in Canada Infrastructure Plan, CBAs are expected to become more common in social infrastructure projects [2].

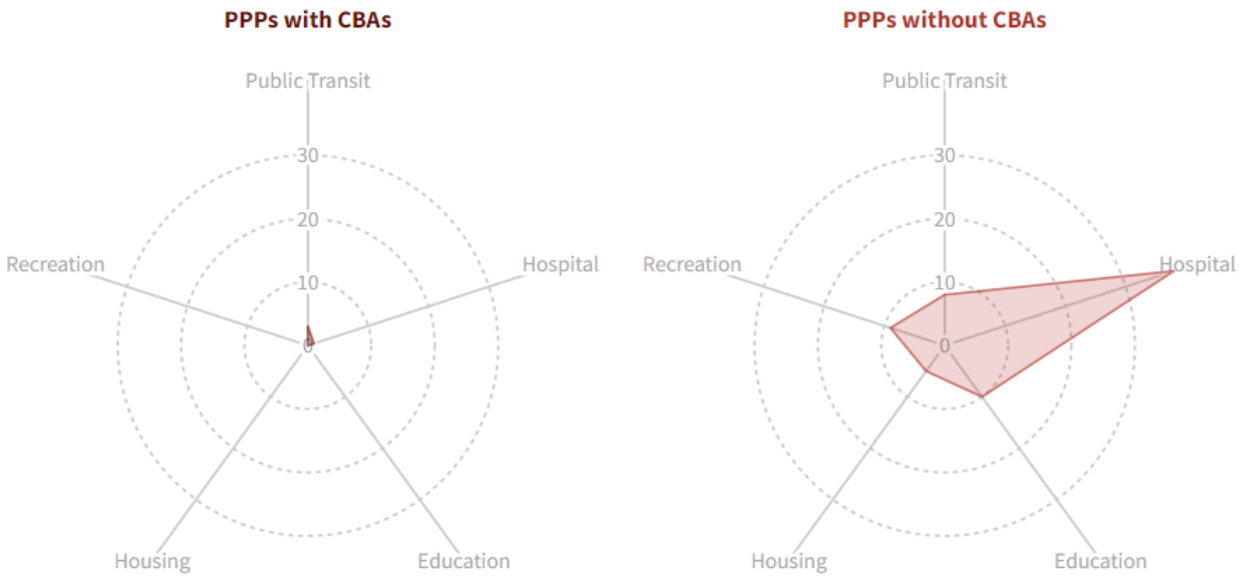


Figure 15. Community Benefit Agreements in Canadian Social Infrastructure Projects

The environmental governance mechanism in Canada often relies on third-party certifications, commonly utilized to ensure the environmental sustainability of projects. Third-party certifications, such as LEED, are standardized rating systems used to evaluate the environmental performance and sustainability of buildings, infrastructure, and other projects. These certifications are typically awarded by CAGBC and assess various aspects such as energy efficiency, water conservation, materials selection, indoor environmental quality, and sustainable site development [96]. LEED is adopted during the early planning stages to ensure social infrastructure buildings are designed, built, and operated to ensure high-performance, cost-effective project outcomes, ensuring they meet high standards of sustainability and environmental responsibility. Other examples of third-party certifications include TRUE which evaluate buildings for zero waste performamance and

ZCB which ensures low-carbon design and operational performance for buildings. Their use in social infrastructure projects is seen in the Figure 16 below [97]

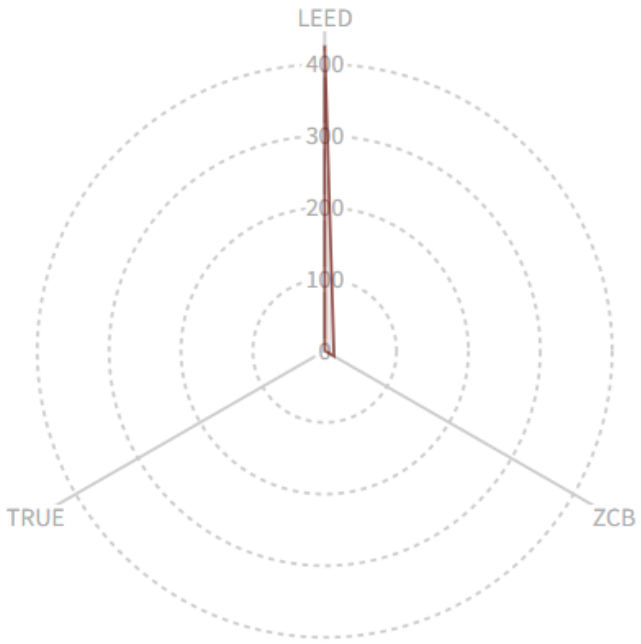


Figure 16. Environmental Certification in Social Infrastructure Projects in Canada

Out of the 3,316 building projects certified under LEED, only 158 hospitals, 360 education facilities, and 202 recreation and culture centres got LEED certification by 2024. Furthermore, only 29 public transit passenger station projects obtained LEED certification. Offices and mixed-use offices had the highest number of certifications, with a total of 1,096 projects [98]. This indicates that social infrastructure projects, particularly in areas like hospitals, education, recreation, and public transport stations, are falling behind in the adoption of environmentally friendly certifications compared to other sectors such as offices and mixed-use spaces. Likewise, out of 144 projects certified with the ZCB standard, only 10 were community and sports facilities, and 5 were education projects. No hospitals or public transit projects received certification. Similarly, the TRUE standard, aiming for zero waste for infrastructure and building projects, has certified 12 projects, none of which are social infrastructure projects covered in this study. Hence, LEED has

been predominantly used for social infrastructure projects as seen in the Figure 16 above and school projects in Figure 17 below.

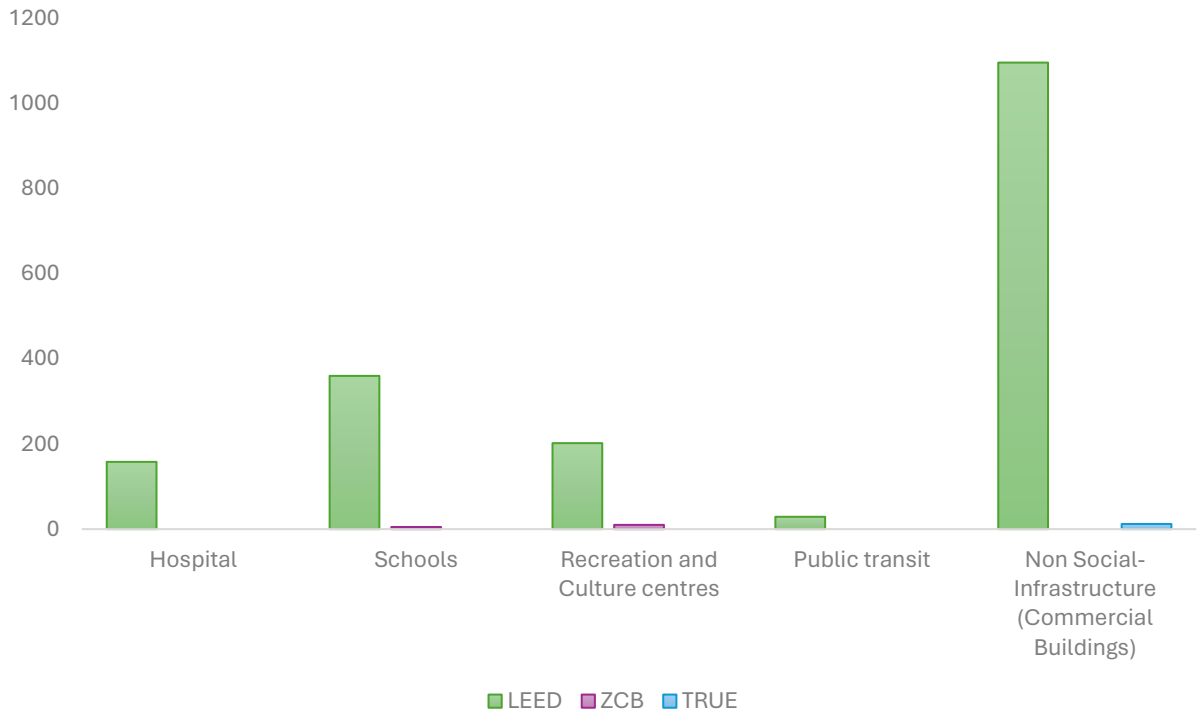


Figure 17. Third-Party Certification in Canadian Infrastructure Projects

The effectiveness of a P3's organizational structure relies on the governance mechanisms put in place, as discussed earlier. These mechanisms directly impact the project's ability to achieve its goals [85]. The above mechanism show the different frameworks addressing governance, environmental, and social aspects, collectively addressing them as ESG issues. The adoption of social and environmental governance mechanisms is still in its early stages and is not active across all project phases. However, recently, the CCPPP introduced a national award category to evaluate projects based on various ESG considerations. This award category could encourage more P3 projects stakeholders to have an incentive for the integration of Environmental and Social governance mechanisms in P3 projects, particularly from the planning phase of P3 procurement, to assess the project's contribution to environmental protection, wildlife protection, climate/GHG

impact, natural infrastructure attributes, Indigenous engagement, community benefits, and other social impact [99]. Hence, ESG governance mechanisms can collectively contribute to the improvement of sustainable and responsible project management for social infrastructure projects in Canada.

2.4. Sustainable and Responsible P3 project management

Sustainable project management refers to the process of minimizing negative impacts and maximize positive outcomes and guarantee the long-term success of projects [14]. Sustainable project management involves examining sustainability factors and how they impact various aspects of projects [100]. Responsible project management emphasizes ethical, social, and environmental considerations throughout the project lifecycle [101]. It prioritizes transparency and accountability among stakeholders, ensuring adherence to ethical practices. The main objective is to optimize stakeholder value by ensuring the successful delivery of infrastructure projects while making ethically sound decisions [102] [103]. In the context of P3 projects, there is a growing recognition of the importance of incorporating sustainability principles factors into the project management process to ensure that projects are developed and managed in a sustainable and responsible manner [104]. Integrating sustainability considerations into project management process is an important step towards achieving long-term sustainability value [105]. It considers how sustainability influences the project opportunities available, the value that can be added, and the challenges that may arise throughout the project management process [106] . This may involve conducting sustainability assessments, defining sustainability criteria for project delivery, engaging stakeholders, and promoting transparency and accountability throughout the project lifecycle as part of project management governance mechanism [107] [108]. Table 11 below provides a summary of existing findings and recommendations for sustainable and responsible project management, including insights on the integration of ESG considerations.

Table 11. Findings and Recommendations for Sustainable and Responsible PM

No	Title	Source	Year	Findings	Gap/Recommendations
1.	Sustainable Project Management: Trends and Alignment	Journal Article	2020	Identified the integration of sustainable practices into project management not only enhances stakeholder value but also mitigates project risks. Additionally, it plays a key role in overall project organizational success within the UAE.	The study lacks specific discussions on sustainability considerations tailored to particular types of infrastructure projects. Additionally, responsible project management has not been adequately addressed.
2.	How project management practices lead to infrastructure sustainable success: an empirical study based on goal-setting theory.	Journal Article	2020	The specific culture, strategy, implementation, and reflection of project management practices in Chinese infrastructure projects were justified, demonstrating their impact on the attainment of infrastructure sustainable success.	More case studies can be investigated to strengthen the correlation between project management practices and the sustainable success of infrastructure projects

No	Title	Source	Year	Findings	Gap/Recommendations
3.	A systematic literature review concerning the different interpretations of the role of sustainability in project management	Journal Article	2021	The researchers found three main perspectives on sustainability in project management: seeing it as a constraint, as a tool to support project goals, and as intrinsic value, forming a business case for sustainability. They also introduced a new definition of sustainable project management, emphasizing a value-oriented approach.	Further research is needed to explore the impact of various project delivery models on integrating sustainability into project management, utilizing empirical methods like case studies. Additionally, there is a need for research in defining the conditions and methods for considering weak and strong sustainability in project management.
4.	Barriers to sustainable construction project management: the case of Iran	Journal Article	2021	The researchers identified three obstacles to adopting sustainable practices in Iran's construction projects: a lack of collaboration, insufficient identification of sustainability objectives in construction projects, and a limited understanding of the benefits of sustainability.	The focus has been on identifying barriers to sustainable project management. More research should focus on the specific considerations required for effective sustainable project management.
5.	Critical Factors to Achieve Sustainability of Public-Private Partnership Projects in the Water Sector: A Stakeholder-Oriented Network Perspective	Journal Article	2021	The study highlights specific factors and challenges in the sustainability of water P3 projects. It delves into factors like ecological awareness, construction quality, ecological designs, and project management capacity that significantly influence the sustainability of such projects.	Future research opportunities in this area could involve exploring additional stakeholder perspectives and focusing deeper into the role of financial investors in influencing project sustainability.

No	Title	Source	Year	Findings	Gap/Recommendations
6.	Building bridges: Unraveling the missing links between Public-Private Partnerships and sustainable development	Journal Article	2022	The study identified a strong link between P3s and the attainment of UN Sustainable Development Goals. It emphasized significant interdependencies between P3s and their potential contributions to social, environmental, and economic aspects.	Further research in the context of P3s, including assessing the environmental aspects of P3 projects and the social acceptance of P3s as a sustainable project model in different contexts.
7.	Investigating the significance of sustainability indicators for promoting sustainable construction project management	Journal Article	2023	The study identified and ranked key indicators for sustainable project management in construction projects. Using the relative importance index, revealed that environmental indicators are considered the most important.	Explore specific project management strategies and their role in achieving sustainability goals in construction projects. Investigate how improved communication channels and practices among stakeholders can positively influence social and ethical aspects of sustainability in project management.
8.	Sustainable Public procurement of infrastructure and Human Rights	Book	2023	It emphasizes the importance of sustainable procurement practices from various perspectives, Through case studies and analysis across social infrastructures sectors such as hospitals and, recreation and sports centres. It addresses challenges faced by different stakeholders, including communities, workers, and service users, proposing solutions to advance the sustainable public procurement agenda	Provides challenges and aspects that give more information on best way to promote infrastructure development that prioritizes sustainability and stakeholder rights.

No	Title	Source	Year	Findings	Gap/Recommendations
9.	Public–private partnerships: a collaborative framework for ensuring project sustainable operations	Journal article	2024	The research focused on understanding factors influencing the operational sustainability of P3s. Using Social Network Analysis and Interpretative Structure Model, it identified weak government leadership and institutional environments as key factors. These factors introduce uncertainties, delays, and inefficiencies during project implementation, impacting the long-term sustainability of P3s.	The study's findings give practical guidance for P3 project management for sustainability considering hindering factors. More research can go into other case studies.
10.	12 Responsible Leadership in Megaprojects	Book	2023	The study outlines four key levels of responsible leadership in megaprojects: Stakeholder relationships, Day-to-day operations, Leadership strategies and Personal qualities of leaders	More research is needed to examine the current role of project managers in megaprojects. This includes identifying the challenges and opportunities project managers encounter when applying responsible leadership principles in practice.
11.	Governing public–private partnerships for sustainability: An analysis of procurement and governance practices of PPP infrastructure projects	Journal Article	2017	Identified that public procurers are facing challenges in defining and measuring social sustainability criteria that can be effectively enforced. Additionally, the current contractual structure of P3s may be better suited for achieving a "weak" rather than a "strong" level of sustainability, as observed in reviewed case studies.	Further research is needed to explore the measurability and weighting of sustainability criteria in evaluating P3 projects across various case studies. Additionally, there's a necessity to review P3 governance contracts to improve the promotion of sustainability goals to be achieved.

No	Title	Source	Year	Findings	Gap/Recommendations
12.	PPP projects: improvements in stakeholder management	Journal Article	2020	Developed a comprehensive framework for managing external stakeholders, featuring dynamic stakeholder identification and consideration of their interests at each project phase.	More case study research is needed to understand stakeholder needs for effectively developing stakeholder management frameworks in P3 projects. Continuous updates are crucial as new stakeholders emerge and existing stakeholders' interests evolve.
13.	Public–Private Partnerships for Environmental, Social, and Governance Projects: How Private Funding for Infrastructure Can Produce Mutual Benefits for Companies and the Public	Journal Article	2022	Examines how P3s can be used as a tool to address ESG issues ensuring mutual benefits for different stakeholders. It focuses mostly on environmental criteria current emphasis on climate change especially in the context of the COVID-19 pandemic.	Future studies could research deeper into the specific mechanisms through which P3s can effectively address ESG challenges.
14.	Project Sustainability and Public-Private Partnership: The Role of Government Relation Orientation and Project Governance	Journal Article	2022	It investigates how the attitude and behavior of the government towards its relationships with private sector entities influence the sustainability of P3 projects. Identifies instrumental and rent-seeking relation orientations directly impacting project sustainability. Also points the role of governance mechanisms as a facilitator between government's relation orientation and project sustainability	The study focuses just on government behavior without considering private sector behaviour and responses. Recommends future research to include private sector behavior, incorporate project characteristics, and conduct case studies for a more comprehensive understanding.

No	Title	Source	Year	Findings	Gap/Recommendations
15.	Influence of Project Governance Mechanisms on the Sustainable Development of Public-Private Partnership Projects: An Empirical Study from China	Journal Article	2023	Contractual, relational, and risk governance mechanisms positively influence P3 project governance performance which in turn positively impacts project sustainability. The study emphasizes the importance of integrating risk governance mechanisms into traditional governance systems for P3 projects.	More research on different types of P3 projects and their governance mechanisms for more detailed insights on their influence to improve project sustainability in various types of P3 projects
16.	A multicriteria decision framework for governance of P3 projects towards sustainable development	Journal Article	2023	The research found that in Ghana, contractual governance is more important for ensuring the sustainability of P3 projects compared to non-contractual factors. Effective risk allocation and communication were highlighted as key elements within contractual arrangements that significantly impact sustainability by influencing their effectiveness and implementation.	Further research should focus on expanding governance factors and investigating their influence on project success. A hierarchical decision framework was created using the DEMATEL method, involving 30 experts to evaluate two main P3 governance factors and eleven subfactors. Alternative methodologies should be considered to further explore P3 governance factors.
17.	Construction of Performance Evaluation Model for the Operation and Maintenance of Government Enterprise Cooperation Infrastructure Projects under the ESG Concept	Journal Article	2023	The study finds the positive impact of the ESG on improving the management of operation and maintenance tasks in P3 infrastructure projects.	This study suggests evaluating the effectiveness of integrating of ESG principles into project management and assessing their impact on project sustainability outcomes

No	Title	Source	Year	Findings	Gap/Recommendations
18.	A systematic review of the interrelation of administrative, Environmental, Social and Governance of Public-Private Partnerships (P3) Spaceport Project in Biak, Papua, Indonesia	Journal Article	2022	The study identifies that there is a need for a more comprehensive approach to integrating ESG considerations into the project. There is risk for challenges arising from the lack of legal clarity and the imbalance between business interests and ESG	The study suggests the importance of integrating ESG considerations throughout the project lifecycle, from planning to implementation to ensure sustainability and effectively mitigate the ESG risks, particularly in culturally and environmentally sensitive regions like Biak.
19.	Public–Private Partnerships and Green Financing of Infrastructure Projects	Part of a book series	2023	The findings emphasize the importance of sustainable and responsible investing based on ESG standards for infrastructure projects.	Future research could explore the effectiveness of green financing mechanisms in P3 projects, examining case studies and comparative studies of successful implementations in different context.
20.	Sustainable Financing for ESG Practices	Part of a book series	2024	The findings examine various sustainable financing alternatives available to organizations, including both traditional financial instruments and innovative funding mechanisms. It identifies the growing importance of sustainable financing in facilitating the implementation of ESG practices within the corporate sector.	Future research could evaluate the effectiveness of sustainable financing methods in achieving ESG goals within the construction sector, particularly in P3 infrastructure projects. Comparative studies could assess the outcomes of contexts that have implemented sustainable financing practices against those that haven't, shedding light on the advantages and obstacles of each approach.

It is clear that considering and integrating ESG aspects throughout a P3 project implementation enhances efficiency and sustainability [19] [55]. ESG issues refer to factors beyond financial metrics that are used to evaluate the sustainability and overall impact of infrastructure projects. They are important determinants of the non-financial value of a project and have been currently used to inform decision making and evaluate non-financial project

performance [19]. By assessing environmental impact, social outcomes, and governance practices, stakeholders can measure how effectively a project aligns with sustainability goals and societal needs. This ESG data assessment is usually specific and largely subjective and vary significantly based on the type of project depending on the stakeholder preferences, policies, and investment priorities [109] [110]. Thus, the early and diverse engagement of stakeholders in defining ESG issues is important to avoid stereotypes and biases. A report by Statistics Canada [111], highlights that Canada should aim to have a standardised ESG assessment guidelines among its provinces while also incorporating the unique values and interests of Indigenous peoples. This implies a recognition of the diversity of Indigenous perspectives and the importance of respecting their contributions to sustainability and governance efforts. Similarly, it is important to conduct ongoing monitoring of the environmental impact assessment for social infrastructure projects to ensure environmental concerns are addressed throughout the project lifecycle. Presently, environmental impact assessments are primarily conducted during the planning stage [112]. However, there is a lack of reported evidence on how various P3 models have monitored and addressed the identified environmental issues throughout different phases of the project implementation.

As described above, P3 projects are typically evaluated based on their potential to deliver high value-for-money, considering factors such as project size, complexity, and innovation requirements. The environmental and social governance mechanism is addressed mostly as additional components to the project agreement rather than integral parts of the project governance structure. To address this gap, the primary objective of this thesis is to identify specific ESG criteria that should be incorporated into the P3 procurement for social infrastructure projects to promote the inclusion of governance mechanisms such as CBAs in PPPs, with the aim of improving social benefits provided by PPP projects in different phases. Table 12 below presents the qualitative ESG criteria identified (see appendix I), along with their respective sources and

their application in assessing various project delivery models. These Canadian-specific ESG criteria are sourced from the identified objectives and challenges in social infrastructure projects, as described in the tables above. Additionally, they are derived from Infrastructure Canada's sustainability objectives, provincial infrastructure plans, and considerations outlined in CBAs and LEED standards. They will serve as the foundation for the proposed ESG-PPP suitability screening matrix, enabling a broader comparison with traditional project delivery models. This procurement approach aims to improve the governance framework, ensuring that projects align with Canada's sustainability goals and deliver long-term benefits to communities considering both core and non-core PPP servives. Therefore, a decision flow chart guiding when to use an ESG-PPP screening matrix for procuring a P3 model, based on evaluated ESG project aspects, is illustrated in Figure 18 below. If the project objective indicates significant environmental, social, or governance impacts, using the ESG screening matrix for P3 procurement is necessary. If the decision indicates no ESG impacts, the project team may prioritize other procurement options without using an ESG screening matrix. Therefore, the decision chart ensures that if any of the questions result in a "Yes" answer, the assessment must be conducted. If all questions result in a "No" answer, then the assessment is not required.

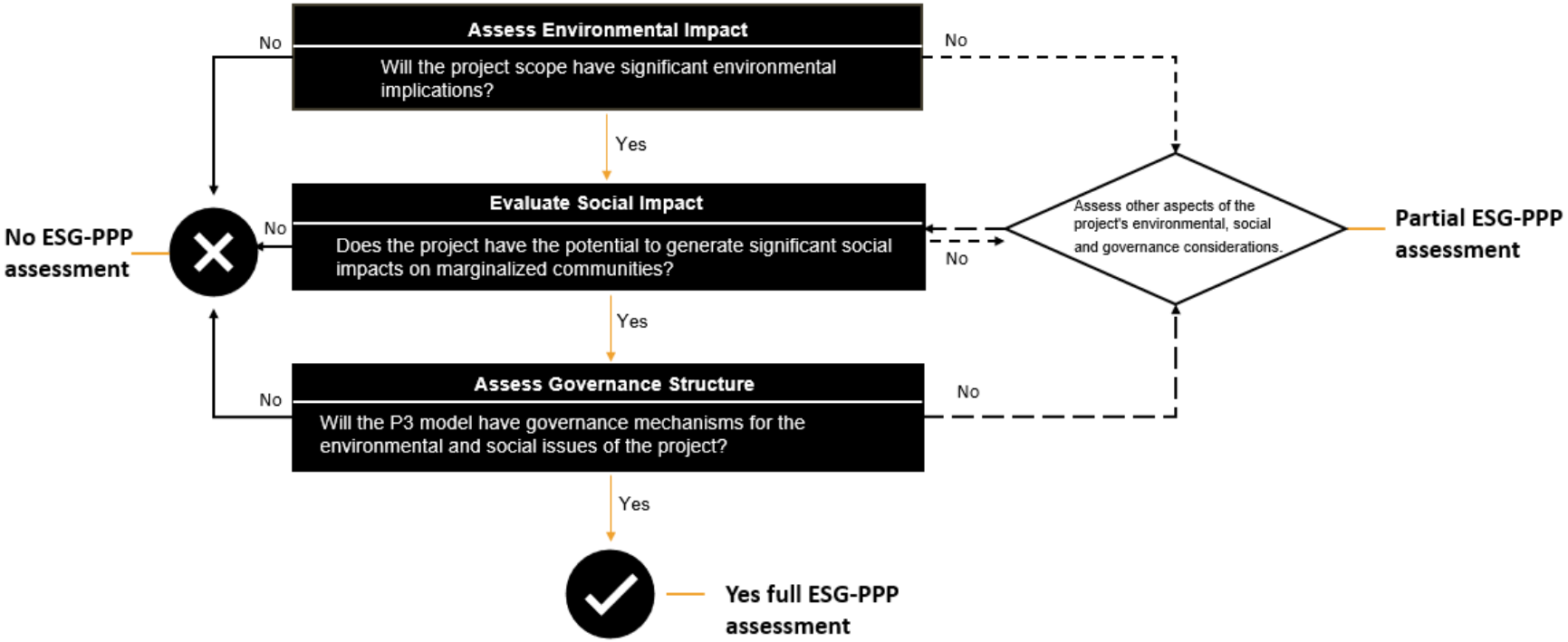


Figure 18. Decision Flow Chart for use of ESG Screening Matrix in P3 Model Procurement

Table 12 Qualitative ESG Criteria for Canadian Social Infrastructure Projects

Qualitative Criteria		**Objectives to be achieved**
	Environmental Sustainability	The goal is to select a project delivery model whose organizational structure and sequencing off activities aligns with the environmental goals of a social infrastructure project.
1	Environmental Criterion	
	Source: Canada green funding programs and Identified challenges in P3 social infrastructure projects	
1.1	**Green adoption incentives** **1. Green expertise partnership** [113] [114] [91] [52] [13] [30] [39] **2. Green funding** [115] [50] [48] [116]	These criteria will evaluate the extent to which project delivery models prioritize environmental sustainability in infrastructure projects. By comparing the sequencing of activities and organizational structures across different project delivery models, the goal is to identify which models are more effective in promoting environmental sustainability through partnerships with green experts and access to green funding sources. This assessment aims to inform decision-makers about the strengths and weaknesses of each model in integrating green practices and fostering environmentally friendly infrastructure development.

DBB	**DB**	**DBF**	**P3**	**Progressive P3**	**P3 Bundle**
The owner may engage green experts independently for design and construction phases. The owner typically bears the risks associated with green technologies and may allocate funding accordingly.	The contractor may have more influence in selecting green partners and accessing funding for sustainable solutions.	Green expertise partnerships and funding mechanisms may be established by the financing entity. The entity providing financing may influence decision-making regarding green practices.	Innovative private sector green funding investment may be employed and may collaborate broadly with private environmental organizations to provide expertise and guidance on implementing sustainable practices.	Green expertise partnerships roles and risks may be established collaboratively during the planning phase. Early involvement of green expertise allows for greater input in decision-making regarding green initiatives from the beginning.	Green expertise partnerships and funding mechanisms may be established for the bundled projects collectively.

	Social Sustainability	The goal is to select a project delivery model organizational structure and sequencing off activities that aligns with the social goals of a social infrastructure project.
2	Social Criteria	
	Source*:* Community Benefits Agreement and Canada Infrastructure program plan [1] [63] [43] [94] [51]	
2.1	**Community benefits** **1. Long/short-Term CBA** **2. Collaborative/Non-collaborative CBA**	This criterion evaluates how project delivery models achieve community benefits based on their structures, processes, and stakeholder engagement. Factors considered include community engagement levels, inclusivity in decision-making, and past performance in delivering community benefits. Models that actively promote more opportunities for marginalized groups, such as indigenous communities, contribute more to community benefits.

DBB	**DB**	**DBF**	**P3**	**Progressive P3**	**P3 Bundle**
Limited involvement of the community during the design and construction phases. Opportunities for local hiring may depend on contractors' practices	Single-point responsibility streamlines decision-making, enabling faster responses to community input and prompt addressing of concerns, reducing bureaucratic delays.	Financing considerations may impact the level of emphasis on community benefits; economic viability often takes precedence.	The long-term integration of project phases may have long-term community job opportunities. Leading to training and long-term local hiring for non-core P3 services.	Early collaboration in progressive P3 models allows negotiation of community benefits during procurement, incentivizing the private sector to deliver social benefits as part of the agreement.	Opportunities for community engagement are maximized within the scope of the bundled small projects.

3.	**Responsible** Governance Criteria ***Source***: Identified challenges in P3 social infrastructure project	The goal is to select a project delivery model organizational structure and sequencing off activities that aligns with the transparency goals of a social infrastructure project.
3.1	**Stakeholder engagement: Transparency and Accountability** [16] [49] [33] **1. Early Engagement** **2. Communication Channels** **3. Decision-Making Structure** **4. Long-Term Stakeholder Management**	This criterion assesses stakeholder engagement in the project delivery model, aiming to choose a model that achieves transparency, involves stakeholders in key decisions, and maintains accountability.

DBB	DB	DBF	P3	Progressive P3	P3 Bundle
DBB's sequential nature limits transparency, accountability as the phases is segmented.	DB offers more collaboration opportunities. Transparency is typically enhanced in DB due to its integrated nature, and accountability is shared within the design-build team, promoting collective responsibility for project outcomes.	Communication in DBF may need to address both construction progress and financial aspects, potentially increasing the complexity of stakeholder engagement. Transparency in financial arrangements becomes a critical aspect.	P3 projects necessitate effective long-term relationship management with stakeholders. Maintaining positive relationships and addressing concerns over an extended project lifecycle	Private sectors collaborate in shaping the project agreement after the RFQ stage, with ongoing stakeholder engagement and joint development of project aspects.	Stakeholder engagement approaches may vary based on the characteristics of the individual bundled projects

2.5. Summary of identified gaps in the literature

Several studies have examined the positive impact of the ESG integration of sustainable practices into project management processes [100] [55]. However, research indicates that these ESG sustainability considerations have not been fully integrated into the procurement and governance practices of P3 infrastructure projects [107]. There is a recognized need for a more comprehensive approach to integrating ESG considerations into infrastructure projects [117]. P3s have been explored as a potential tool to address ESG issues, with suggestions for further research into how they can effectively manage ESG challenges across the project lifecycle, from planning to implementation [55] [118] [104]. Likewise, in the Canadian context, three main gaps have been identified in existing procurement assessments: the absence of Canadian-specific ESG procurement evaluative criteria for P3 social infrastructure projects, the lack of integration of ESG aspects in the procurement process, and the exclusion of ESG aspects in the multi-criteria analysis for selecting the best P3 model to compare against VfM considerations. This thesis aims to contribute to the integration of ESG sustainability considerations in procuring P3 social infrastructure projects in Canada by evaluating how well the P3 model achieves ESG sustainability in infrastructure projects. Figures 19 and 20 below summarize identified gaps, proposed contributions, and the current necessity for integrating ESG factors in the procurement evaluation of a P3 model. These contributions address literature gaps in three key areas: establishing environmental, social, and governance criteria for assessing responsible sustainability management in Canadian P3s; introducing a new assessment process, a screening matrix for evaluating ESG criteria in social infrastructure projects; and developing an AHP selection model tool for selecting P3 model types, considering both ESG qualitative and VfM quantitative aspects.

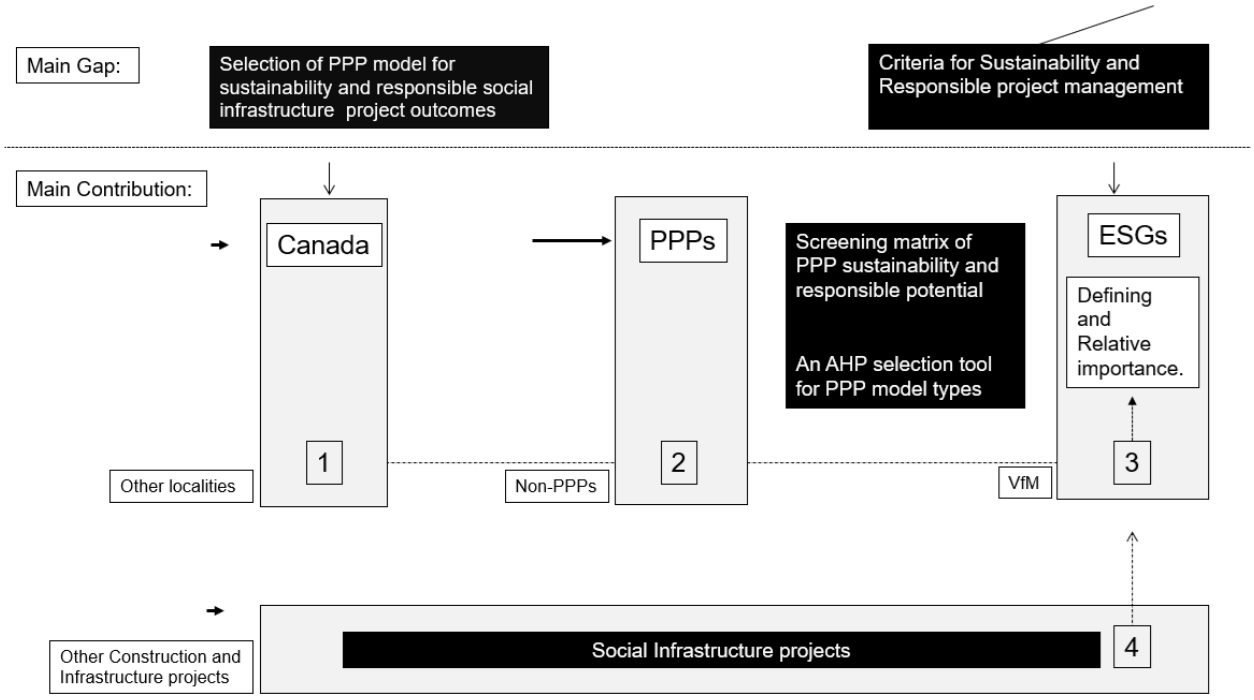


Figure 19. Literature review gaps

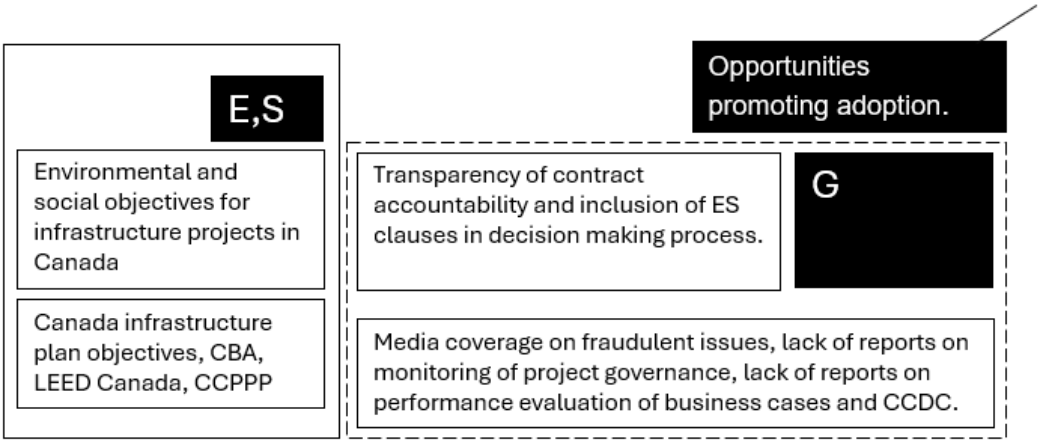


Figure 20. Need for Integrating ESG Factors in Procurement evaluation of a P3 model

Chapter 3: Methodology

3.1. Introduction

This chapter outlines the methodology used to achieve the second and third objectives of this thesis, divided into two sections for clarity. The first section, 3.2, details the development of the ESG-PPP screening matrix. It outlines the process of identifying the ESG criteria, the weighting and scoring mechanism, and the decision thresholds. Additionally, it explains the rationale behind the ESG-PPP assessment matrix structure. Section 3.3 will cover the selection process of the AHP methodology and explain why it was chosen. It will detail the steps involved in its selection process, highlighting the importance of low inconsistency performance in AHP scales. The AHP scales will therefore be described, including the criteria used for the selection of the comparative scale that will be examined in the fourth chapter. Also, the hierarchy structure for selecting sustainable and responsible P3 models will be illustrated and explained.

3.2. Development of the Screening Matrix

The screening matrix is developed to evaluate the potential of P3s to achieve sustainability and responsible project management in Canadian social infrastructure projects. It will use three dimensions: Environmental, Social, and Governance, each with its own set of evaluative criteria. These evaluative criteria may vary depending on the different types of infrastructure project evaluated. Thus, for the scope of this study, the ESG criteria used are defined based on common ESG objectives and project requirements identified for hospitals, schools, public transit, social housing, recreation, and cultural centers. Each criterion will have a set of questions, each with response indicators rated on a 1-5 scale. The total score for each ESG dimension will be calculated by normalizing and combining the criterion responses. Then, each dimension total will be combined to determine if a P3 model is satisfactory to deliver sustainable and responsible project management. This assessment approach will provide a structured framework for decision-

making, enabling stakeholders to make informed choices based on an analysis of the nonfinancial ESG aspects that play an important role in improving overall project success and value creation. The following steps were followed in the development of the ESG-PPP screening matrix as illustrated in the Figure 21 below.

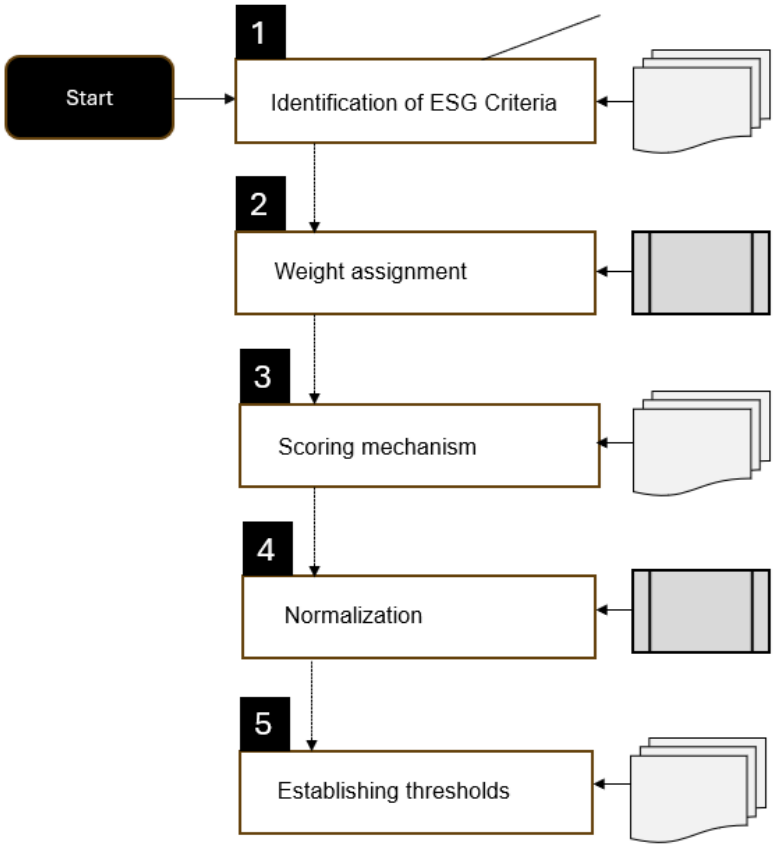


Figure 21. Process Flow Diagram for Screening Matrix Development

Step 1: The criteria identification process systematically gathered and refined relevant ESG criteria for the assessment matrix. First, a thorough literature review was done to extract the ESG criteria. This process included analyzing federal sustainability reports, provincial and federal infrastructure plans, sustainability publications from the Canadian infrastructure industry, and relevant guidelines. Additionally, project-specific ESG objectives, requirements, and current P3 news coverage from sources like CCPPP and other news websites were considered. Throughout the process, careful attention was given to refining the identified criteria, eliminating duplicates,

consolidating similar ones, and ensuring alignment with the research goals. Although stakeholders were not directly involved, the identified criteria were checked for relevance and coherence to ensure they collectively represented a complete ESG set of factors aligned with the research objectives. The following were the identified ESG evaluative criteria scope for the Canadian context, as illustrated in Figure 22 below:

1. The environmental dimension focus on green practices with positive ecological, climatic, and resilience impacts assessing green adoption incentives including green funding and green private expertise. The questions measure the availability and degree to which a P3 model allows for partnership with private entities with environmental expertise such as CAGBC and the incentives provided within the P3 model organization structure to have private funding with environmental conscious investors to encourage sustainable and environmentally friendly practices.
2. Social dimensions emphasize community benefits, assessing the adoption of community benefit agreements, community engagement, and inclusivity. The questions measure how the P3 structure and sequencing of activities influences the nature and scope of using the community benefits agreements, either emphasizing and prioritizing immediate gains or long-term sustainability and if they are developed collaboratively with community stakeholders.
3. Governance dimensions assess ethical practices and adherence to governance frameworks, ensuring transparency and accountability in stakeholder management and decision-making processes. The questions measure how the P3 model organisation structure influences the overall decision-making processes within the project team and other stakeholders, involving the formulation, discussion, communication, finalization, and implementation of project agreements.

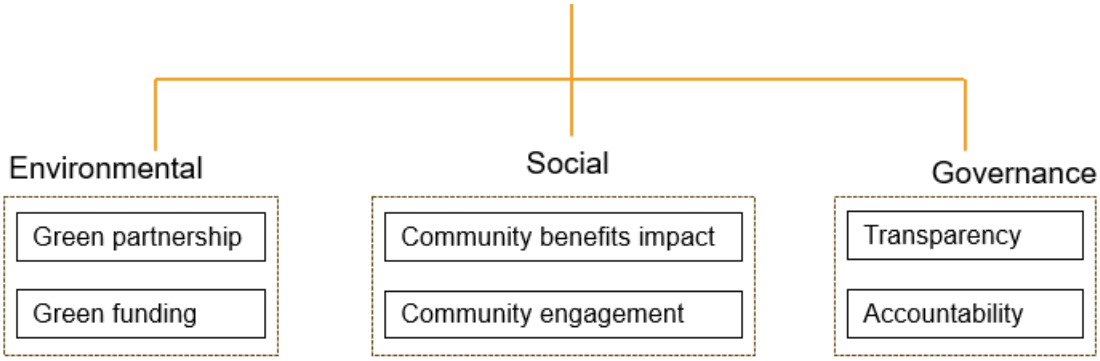


Figure 22. ESG dimension and evaluative criteria for the ESG-PPP screening matrix

The criteria within each of the ESG dimensions align with the broader goals of the Canada Infrastructure Plan. However, as mentioned earlier, these ESG evaluation criteria may change. The project team has the flexibility to suggest new ESG criteria to tackle current issues and challenges specific to a project category. This is important as the P3 model evolves and adjusts over time.

Step 2: Weighting involves assigning relative importance to each criterion. Weighting is applied prior to scoring and determines the impact that each criterion will have on the final decision. Criteria with higher weights contribute more to the overall assessment, while criteria with lower weights have less influence. Hence, assigning weights to criterion is a subjective process and depends on the decision problem [119]. Existing assessment matrices like P3 Canada's and British Columbia's use both quantitative and qualitative subjective weighting methods [69] [66]. The objective method uses a mathematical function to calculate weights based on criteria information [120], while the subjective method relies on decision makers' numerical weighting preferences [121]. Therefore, different contexts may call for different approaches based on available data; however, the selected method should align with the overall decision goals [122]. In this ESG-PPP assessment matrix, all identified project objectives and challenges are considered equally important. Therefore, the preferred weighting preference assumes that all ESG criteria hold equal importance for evaluating the sustainability and responsibility of the P3 model in social

infrastructure projects. Thus, a quantitative objective weighting method, specifically the equal weight approach [120], is chosen. This method is often used when criteria are considered equally important, allowing stakeholders to assign equal weights to each criterion. By using this approach, the subjective nature of the matrix is reduced compared to using subjective weighting methods. In different ESG-PPP screening process, other weighting methods can also be considered as ESG decision considerations evolve. Table 13 below summarizes the available weighting methods and their application in the existing Canadian P3 suitability matrix.

Table 13. Criteria Weighting Methods

Weighting method	Description / Equation	Assumptions	Type	Application of weighting methods in the existing Canadian P3 suitability matrix
Points allocation	A total of 100 points is distributed among the criteria based on their relative importance.	The importance of criteria in P3 selection varies	Numerical Subjective	P3 Canada P3 suitability assessment matrix
Ordinal Scale	Criteria are weighted using ordered categories.	The importance of criteria in P3 selection varies	Qualitative Subjective	British Columbia option procurement analysis.
Equal weights	$W_j = \frac{1}{n}$, n is the number of criteria [120]	All criteria equally impact P3 selection.	Quantitative Objective	Proposed ESG-PPP screening matrix

Step 3: Scoring involves assigning numerical values to criterion based on their performance. It is used to quantify the degree to which each criterion meets the predefined ESG objectives. Different scores can be applied to different criterion [119].However, this matrix uses the same scoring rating for all criteria similar to the existing P3 Canada choice of scoring scale. The scoring scale is a 5-point scale to rank responses numerically, indicating how effectively the objectives of an ESG criterion will be met. Each number from 1 to 5 represents a level of response or opinion, with 1 typically indicating the lowest or least favorable impact, and 5 indicating the highest or most favorable impact. The scoring scale allows stakeholders to express how the criterion will be

achieved based on the P3 model characteristics. The scores measure the extent to which the criterion is satisfied facilitating the quantification of the ESG impact for analysis to establish decision thresholds. Table 14 below shows the summarised criteria weights and the scoring scale considerations.

Table 14. Criteria Weighting and Scoring

Criteria	Dimension weight	Scoring Subjective	Rationale
Environmental aspects: Green adoption incentives	33.3%	Scoring Range: 1 to 5 points (Weighted range: 0.33 to 1.665)	Incentives for adopting green practices significantly contribute to the overall environmental sustainability of the project, including access to green funding and expertise.
Social aspects: Collaborative/ Long-term CBA	33.3%	Scoring Range: 1 to 5 points (Weighted: 0.33 to 1.665)	The impact of community benefits varies across different phases of a project, and the collaborative efforts involved in achieving these benefits play an important role in promoting social sustainability.
Governance aspects: Stakeholder management	33.3%	Scoring Range: 1 to 5 points (Weighted: 0.33 to 1.665)	Effective stakeholder management is important for project governance success. When stakeholders are actively engaged in a transparent manner, they are more likely to hold project managers and key stakeholders accountable for achieving objectives and delivering results throughout the project lifecycle.

Step 4: Normalizing criterion scores is important when different scoring methods are used for various response indicators of the criterion. In this assessment matrix, the same scoring rating, with a maximum of 5 points, was applied uniformly across all indicators. Therefore, normalization of the scoring was not necessary.

Step 5: To establish decision thresholds, each of the six criteria contributes equally, contributing 16.7% to the overall evaluation. Scores of 4-5 contribute positively, scores of 3 contribute neutrally, and scores of 1-2 contribute negatively. Getting the total score begins by calculating the weighted

scores this includes multiplying the criterion scores by their corresponding weights. The criterion weighted score has the lowest possible score of 1, resulting in a weighted score of 0.167, and the highest possible score of 5, resulting in a weighted score of 0.835 for the criterion. Subsequently, the weighted scores are summed up to obtain the total weighted scores for each dimension. Which are then summed up to get an overall weighted score. The overall weighted score has the lowest possible overall score of 1.002, and the highest is 5.01. Therefore, thresholds in Table 15 below categorize P3 suitability for sustainability and responsible outcome based on scores ranging from 1.002 to 5.01. Scores below 2 indicate unsatisfactory P3 performance, while scores above 4 indicate satisfactory P3 performance. These thresholds aid in screening P3 model sustainability, ensuring alignment with environmental, social, and governance criteria.

Table 15. P3 Procurement Decision Thresholds for Responsible Sustainability

Decision thresholds	Description
4-5	Satisfactory
3	Adequate: Represents a moderate level of performance where certain aspects of the project may require additional efforts or resources to bring the P3 model up to satisfactory levels.
1-2	Unsatisfactory

This screening matrix developed was informed by P3 Canada's established screening assessment matrix, which is considered an industry standard [69]. Although involving stakeholders in developing the matrix structure components would benefit the matrix development [20], it was not implemented in this specific thesis due to constraints such as time, resources, and the unavailability of key stakeholders. Conducting extensive stakeholder discussions was not practical. Instead, the available P3 Canada matrix reference provides a familiar and credible structure for the ESG-PPP assessment matrix, ensuring consistency, acceptance, and alignment with industry practices, especially for stakeholders already accustomed to its structure.

After following the outlined steps and developing the screening matrix for assessing P3 suitability in terms of sustainability and responsibility, the next objective is to create a model for selecting the appropriate P3 delivery model. This model will consider both qualitative and quantitative VfM analysis results, facilitating the procurement decision multi-criteria options analysis outlined in the P3 procurement guide [68] [123].

3.3. Analytical Hierarchy Process for procurement of P3 options

Various multi-criteria decision-making methods are available, each suited for different decision problems [124]. In the case of the P3 model type decision problem, the AHP method was chosen. This decision was made because the problem involves a set of criteria and alternatives that can be organized in a hierarchy structure. Within this structure, the relative importance of each criterion and alternative to each criterion can be calculated using pairwise comparison. The resulting number of pairwise comparisons is relatively manageable, given the number of criteria and alternatives [125], which maintains ease of comparison and prevents complexity. Specifically, this selection problem involves evaluating five P3 model alternatives across four criteria: environmental, social, governance, and value-for-money aspects. These criteria and alternatives can be organized into a hierarchical structure, where consistent judgments and comparisons are made at each level. The AHP methodology excels in managing decision problems that include both quantitative and qualitative criteria within a hierarchical structure. It effectively handles subjective opinions from stakeholders and prioritizes criteria or alternatives based on their relative importance. Through this structured approach, stakeholders' subjective opinions on criteria importance are quantified into numerical weights for objective selection, making it more inclusive and better suited to real-world complexities [126] [127]. Given that the decision problem of the P3 model aligns well with the characteristics offered by AHP, it is chosen as the preferred approach. The key process steps followed in the development of the AHP-PPP selection model is illustrated in Figure 23 below.

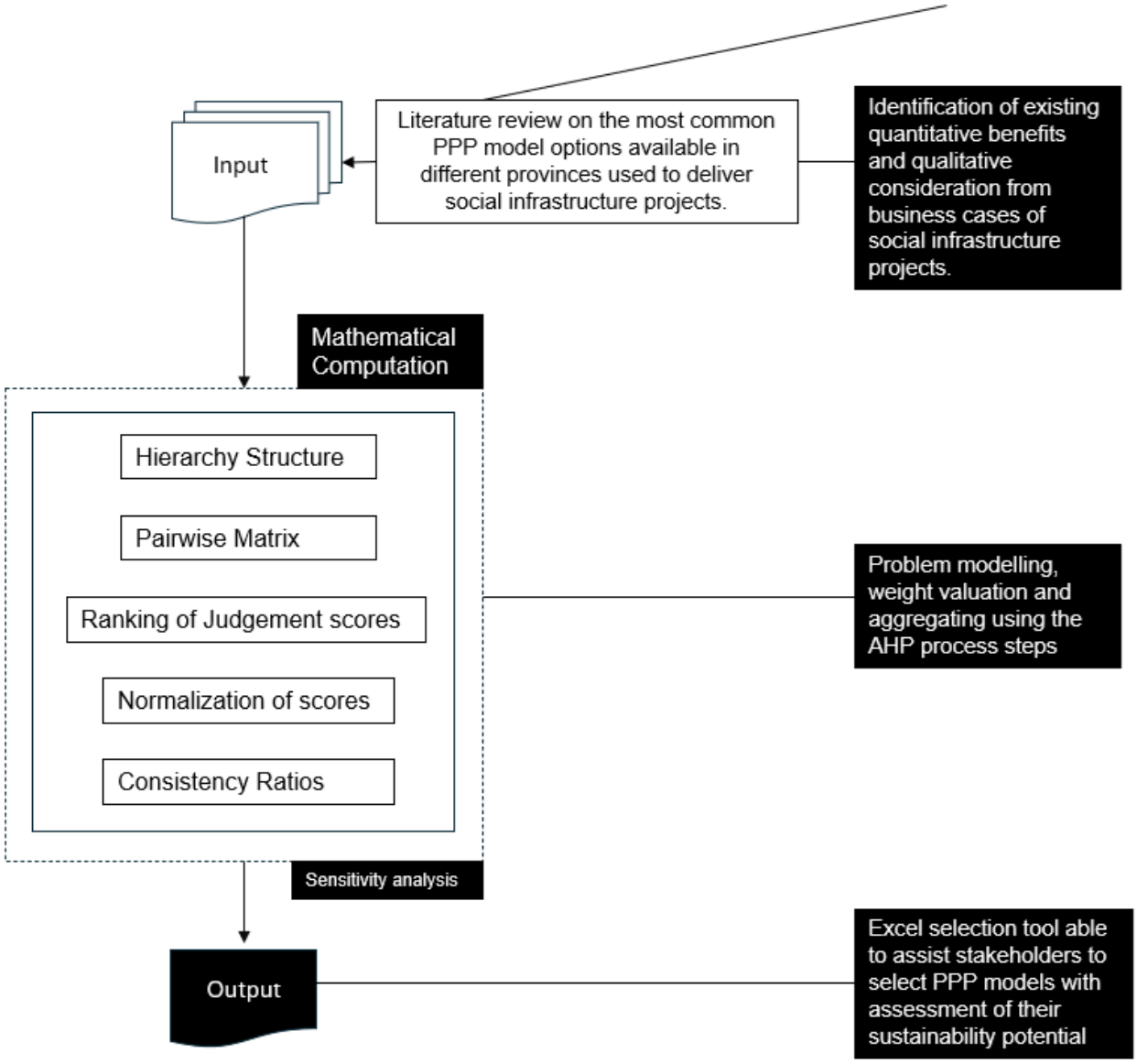


Figure 23. AHP Development Process Flow Diagram

With reference to the above stages. The following are the steps followed in creating the selection model for this P3 model type selection decision.

Step 1: **Hierarchy Structure:** The initial step involves the formulation of the selection problem within a hierarchical structure. The hierarchical structure proposed within the scope of this study consists of four levels as seen in Figure 24 below.

- **Level 1**: The main objective of the selection problem is to choose a P3 model that considers the best sustainability and responsible project delivery practices for a social infrastructure project. This is put as the highest level.
- **Level 2:** This level represents the main criteria or aspects that contribute to the overall decision of the main objective. The four main criteria for comparison are the identified qualitative environmental, social, and governance criteria, along with the quantitative aspect of the Value-for-money achieved from previous P3 projects. These criteria are independent to avoid redundancy as this can lead to inconsistencies and make the decision-making process less reliable. If criteria are highly correlated or redundant, it can lead to double-counting or overemphasizing certain aspects of the decision [128]. Each criterion is defined on how it is to be evaluated to fit within the context of this hierarchy structure as follows. It includes all considerations constituting the proposed National ESG category award by the CCPPP [129].

    a. Environmental

    The environmental criteria assess each P3 model's capacity to address Canada-specific aspects such as environmental protection or enhancement, climate change mitigation, wildlife conservation, and natural infrastructure attributes [129]. For example, when working on a construction project in a sensitive environmental area. The choice of P3 model can influence how well the project team, phases, and sequencing of activities may favor protecting local wildlife habitats and minimize environmental impact. As such a model like DBFM may prioritize environmental protection by integrating sustainable construction practices and minimizing environmental impact throughout the project lifecycle. DBFOM models could emphasize long-term environmental management through ongoing operations and maintenance practices. Progressive DBFM and Progressive DBFOM models might

offer innovative solutions for addressing specific environmental challenges, while P3 Bundle models may provide comprehensive approaches to managing environmental considerations across multiple projects within the bundle. Each P3 model brings unique advantages and considerations for addressing environmental concerns, influencing project delivery strategies accordingly.

b. Social

The social criteria involve assessing each P3 model to address Canada specific aspects like Community engagement, social inclusion involving indigenous peoples, and other social impacts. For example, social infrastructure projects require to attain social value outcome governed under a community benefits agreement. A DBFM model often involves a single private entity responsible for designing, building, financing, and maintaining the infrastructure. In this setup, the private partner may have more control over subcontracting and procurement decisions, potentially impacting job training opportunities and the involvement of local businesses and social enterprises during construction. On the other hand, a DBFOM model, where the private partner also operates and maintains the infrastructure, may provide additional incentives for the private entity to allows for ongoing collaboration between the public and private sectors throughout the project lifecycle, facilitating the long-term non-core services contracts promoting more operational opportunities. Progressive P3 models enable stakeholders to iteratively refine social value deliverables and ensure that they remain relevant throughout the project. On the other hand, P3 bundle models can enhance the coordination of social value considerations across different sub-projects and maximize their collective impact on job creation, local procurement, and community development.

c. Governance

The governance criteria involve assessing each P3 model's ability to address Canada specific P3 challenges focusing on stakeholder management to ensure transparency and accountability. In DBFM projects, while governance aspects may be outlined in the contract, the direct accountability on governance practices is limited during construction. The DBFOM models that include operation and maintenance responsibilities can enhance governance by promoting ongoing accountability and transparency throughout the project lifecycle. The progressive P3 models can facilitate the incorporation of robust governance mechanisms to prevent fraud and corruption as all stakeholders are involved in the early stages to ensure transparency and accountability before the project agreement is finalised. The P3 bundle may have a comprehensive governance framework that spans across all bundled projects, promoting consistency, efficiency, and accountability in governance practices.

- **Level 3:** This level represents the available options that are to be selected from. It consists of the commonly used P3 model options for delivering social infrastructure projects in Canada, which are DBFM, DBFMO, progressive P3 models (progressive DBFM and progressive DBFMO), along with the P3 bundle model.

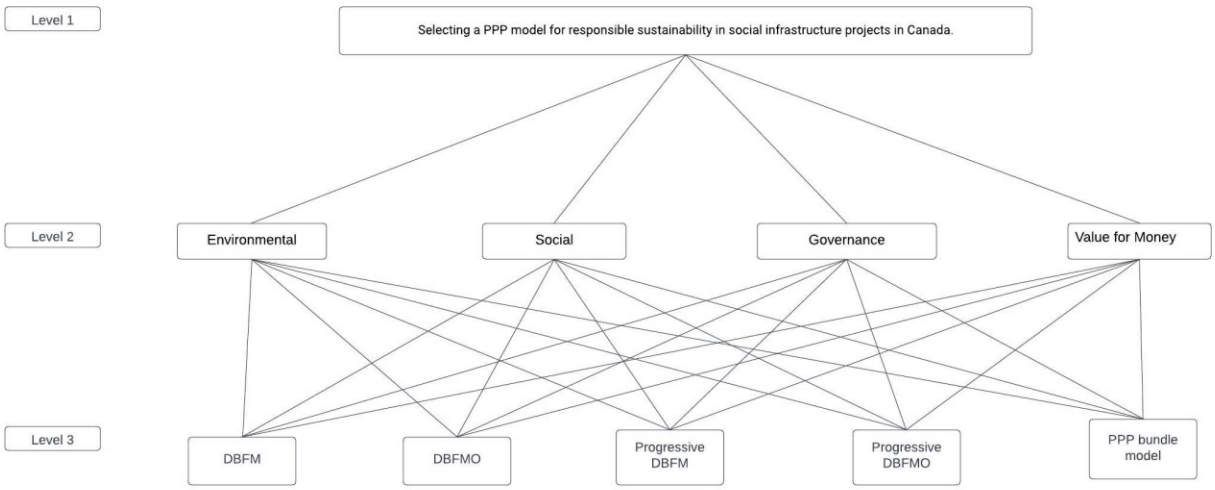


Figure 24 Hierarchical Structure for Selecting Sustainable and Responsible P3 Models

The hierarchical structure is an important part of our AHP selection model, significantly influencing the quality of decision-making. The number of pairwise comparisons made in an AHP is determined by the number of options or criteria on the hierarchy structure. Ongoing research also highlights concerns about potential inconsistencies possible in the AHP, particularly when dealing with numerous pairwise comparisons due to a large number of criteria in a hierarchy structure [130]. To avoid complexity and mutual dependency, this thesis limits the evaluative to four mutually independent criteria, without any sub-criteria. Hence, after all levels are defined, the decision-making process to choose the best P3 model aligning with responsible and sustainable practices for social infrastructure development in Canada follows the steps outlined in Step 2. Figure 25 below illustrates the key stages following to the creation of the hierarchy structure for the selection problem.

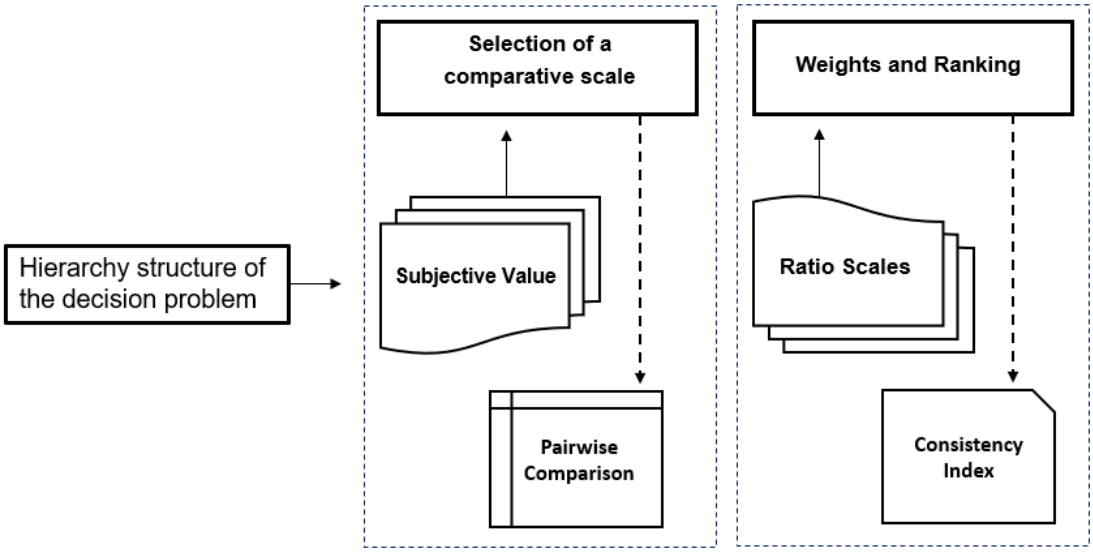


Figure 25 Key Stages Following Hierarchy Structure Establishment

Step 2: Establish a Scale: The calculation of weights depends on the chosen scale, which in turn influences the dispersion and uncertainty of the priority weights [131]. Hence, the selection of the appropriate scale is an important aspect of the AHP methodology and can impact the accuracy and reliability of the decision-making process. This step requires to identify a numerical scale to express the relative importance or preference between the elements in order to convert subjective judgments into quantitative scores. Several types of scales have been employed to represent the relative significance of pairwise comparisons of criteria in an AHP process [132]. Figure 26 categorizes these scales based on the highest value assigned to the decision matrix.

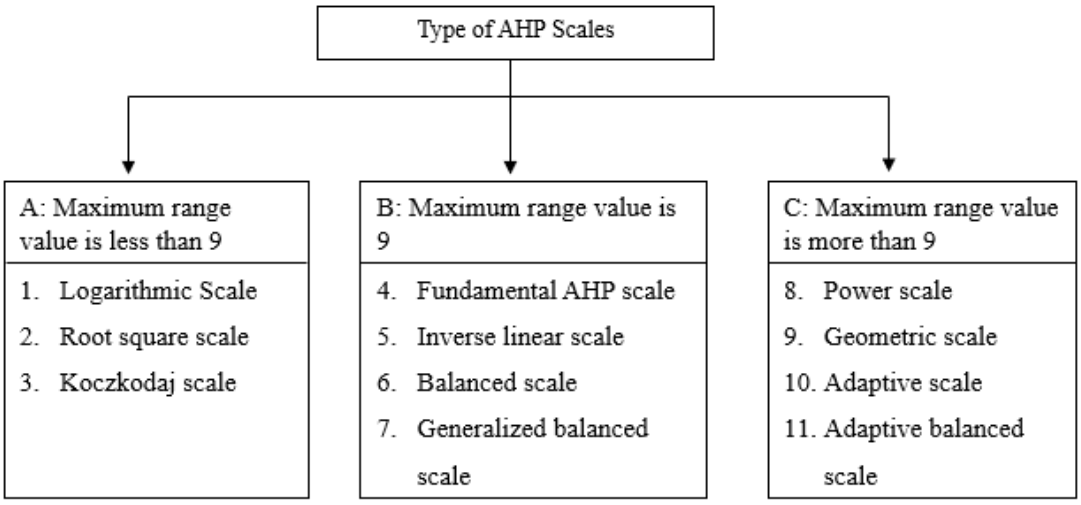


Figure 26. Different types of AHP scales

Among the scales falling under category B, the generalized balanced scale improves both weight dispersion and uncertainty compared to the fundamental AHP scale. Weight dispersion measures the evenness of weight distribution across criteria, while weight uncertainties reflect the confidence in the assigned weights. Higher weight uncertainties imply greater ambiguity, while lower uncertainties indicate more confidence. Similarly, higher weight dispersion suggests wider variation in assigned weights, whereas lower dispersion implies more even distribution. Practical AHP applications demonstrate that the generalized balanced scale leads to better consistency ratios, indicating improved reliability in decision-making processes [133] [131].

Hence, this study will compare P3 model type results using both the fundamental AHP scale and the generalized balanced scale to assess if improved consistency ratios influence the results differently. The fundamental scale where 1 means both criteria are equally important or have equal preference, and 9 indicates one criterion is extremely more important or preferred than the other. Intermediate values represent varied degrees of importance or preference [134]. The balanced scale, proposed by Salo and Hämäläinen, addresses the issue of disproportionate weight changes in the Fundamental AHP scale. They found that small adjustments in judgments at the extreme ends of the scale lead to significantly larger changes in weights [135]. To achieve

equal weight distribution, it is recommended to use a point scale ranging from 1 to 9, structured according to integer ratios provided in Table 16 below, under the Balanced scale preference input. This adjustment addresses the uneven weight distribution issue identified in the Fundamental AHP scale for problems with only two criteria. However, when a decision problem involves more than two criteria, the weight distribution becomes uneven [133]. The generalized balanced scale builds upon this concept, extending its application to decision problems with multiple criteria while maintaining consistent weight distribution by accounting for the number of criteria involved [135]. This thesis plans to use case studies and compare results to assess whether the two scales produce different outcomes given the identified weight distribution variations. Existing research has focused relatively more on studying inconsistency in pairwise comparisons, particularly those aimed at reducing the iterative processes involved [130] However, there is a lack of studies exploring inconsistency results when using different AHP scales across various case studies [136]. Table 16 below shows the mathematical function used to change the range scale of 1 to 9 into integer ratios for the balanced scale and the generalised balanced scale.

Table 16. The comparative scales

x	Definition	Fundamental AHP Scale $C = x$	Balanced $\left(C = \frac{9 + x}{11 - x} \right)$	Generalised balanced (bal-n) $\left(C = \frac{9 + (n-1)x}{9 + n - x} \right)$ Where level 2, n=4 Level 3, n=5	
			n = 2	n = 4	n = 5
1	Equal	1	1	1	1
2	Equal/Moderate	2	1.22	1.36	1.42
3	Moderate	3	1.50	1.8	1.91
4	Moderate/Strong	4	1.86	2.33	2.3
5	Strong	5	2.33	3	3.22
6	Strong/Very Strong	6	3.00	3.86	4.125
7	Very Strong	7	4.00	5	5.29
8	Very Strong/Extreme	8	5.67	6.6	6.83
9	Extreme	9	9	9	9

Step 3: Pairwise matrix: This step compares each criterion against every other criterion using the established scale in a matrix form. A pairwise comparison answers the question of how essential one criterion, say value-for-money for a DBFM, is in relation to the green adoption incentive that DBFM model will has given its phase integration characteristic.

- The pairwise comparison begins with paired comparison matrices for each hierarchy level as illustrated in Figure 27 below were the rows and columns represent the comparison between two criterias. For this study a total of 6 paired comparison should be done for level 2 and 4 for level 3 with respect to level 2. A higher number is assigned if one of the criteria is more important than the other and the reciprocal is assigned if the opposite is considered more important.
- The comparisons on level 2 include: “Green practices” vs. “Community benefits”, “Green practices” vs. “Value-for-money”, “Green practices” vs. stakeholder engagement, “Community benefits” vs. “Value-for-money”, Community benefits vs. Value-for-money, stakeholder engagement vs. “Value-for-money” in relation to the primary objective of selecting the optimal sustainably responsible P3 model. The comparison on level 3 should be compared to the level 2 criteria in a similar manner.

The effectiveness of this approach will highly depend on the responses to the criterion comparison questions, which are formulated on the chosen scale of judgment.

Criterion “n”	A_1	A_2	A_3	A_4
A_1	S_1	S_5	S_9	S_{13}
A_2	S_2	S_6	S_{10}	S_{14}
A_3	S_3	S_7	S_{11}	S_{15}
A_4	S_4	S_8	S_{12}	S_{16}

Figure 27. Pairwise matrix

Step 4: Normalisation process: This step follows to standardise the preference values in the pairwise matrix in a range of 0 to 1, known as eigenvectors. These decomposed matrices as seen in Figure 28 below accurately reflect the relative importance of the compared options with respect to the comparison goal on each level of the hierarchy structure. The formula for calculating the weights as proposed by Saaty [134] is expressed below as:

$$Normalised\ weight, n\ = \frac{Preference\ Score}{Sum\ of\ scores\ for\ the\ column} \tag{1}$$

$$\begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & A_3 & A_4 \end{array} \\ \begin{pmatrix} W_1 & W_5 & W_9 & W_{13} \\ W_2 & W_6 & W_{10} & W_{14} \\ W_3 & W_7 & W_{11} & W_{15} \\ W_4 & W_8 & W_{12} & W_{16} \end{pmatrix} \end{array}$$

Figure 28 Normalised Matrix

After, the principal eigenvector is calculated, the normalised principal eigenvector [134] is calculated as expressed below as:

$$Normalised\ weight, n\ = \frac{1}{3}\ \times Normalised\ weights\ matrix \tag{2}$$

Once the weights are known for each level, the eigenvectors are employed in the determination of the major eigenvalue [128], which serve an important input in checking the coherence of subjective judgments made during pairwise comparisons. The following formula [134] summarised the mathematical procedure used.

$$\lambda_{max} = \sum (\ eigen\ vector\ \times sum\ of\ scores\ of\ the\ column) \tag{3}$$

Step 5: Consistency Verification: This step is taken to ensure logical consistency between the preference values of the decision-makers in the normalized matrix and the derived eigenvectors [128]. The measure of consistency is given as a consistency index as shown in formula below as proposed by Saaty [134] , and used to calculate the consistency ratio [134]. Some inconsistency is expected and allowed in AHP analysis. However, if the consistent ratio is lower or equal to 10%, then the inconsistency is acceptable. The random index Table 17 below highlights the values used.

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{4}$$

$$CR = \frac{CI}{RI} \tag{5}$$

Table 17. Consistency indices for a randomly generated matrix *[134]*

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Step 6: Combining priority vectors and choosing the highest priority: The priority vectors (weights) obtained for criteria and alternatives at each level are combined. This involves aggregating the weights assigned to different criteria and alternatives within the hierarchy. The combined set of weights represents the overall priorities of the alternatives in the decision hierarchy. Finally, the alternative with the highest overall priority is considered the most favorable or suitable choice.

Steps 1-6 of the AHP method explain the key processes involved, along with why they're important. AHP provides a clear way to measure subjective opinions, making it ideal for choosing a P3 model for sustainable social infrastructure projects. Considering this, and the need for a simple decision-making tool, AHP was chosen. Additionally, this iterative process, which involves

creating a priority list at each level of decision-making and selecting the best alternative, has been automated using an Excel tool developed alongside this thesis (see appendix III). This tool will be used in the next chapter to analyze selected case studies, using the two scales as discussed above. The aim is to analyze and discuss the outcomes of the selected P3 model for the social infrastructure case studies.

Chapter 4: Application of AHP-PPP Excel Tool

4.1. Introduction

This chapter aims to demonstrate the functionality and reliability of the developed AHP-PPP Excel tool for selecting a P3 model with the best sustainable outcomes in delivering and managing social infrastructure projects. Section 4.2 will outline the criteria used in selecting the case studies, each case is described together with the scope and objectives and present the outcomes of the P3 model selected using the developed AHP-PPP excel tool made using the Macros and VBA Scripts, which automated the AHP process tasks. The focus of the results will be on the AHP scales consistency in assessing the ESG and VfM project objectives across the selected three case studies. Following that, Section 4.3 will discuss the results comparison of the two AHP scale, as discussed in Chapter Three.

4.2. Case Study Selection

Three social infrastructure projects have been chosen as case studies for analysis within the proposed AHP-PPP model selection tool. The selection criteria include the scale and type of the social projects, availability of P3 model value-for-money data, and the ESG governance mechanism used. Based on these criteria, the selected case studies are the South Niagara Hospital, Finch West Light Rail Transit, and the Saskatchewan Joint Use School Projects.

4.2.1. Case study 1: South Niagara Hospital

4.2.1.1. Case description

The South Niagara hospital is located in Ontario with a size of 1.3 million square feet [137]. It is currently under construction after a 10-year planning period [138] and is scheduled for completion by 2028. It represents an important example of the implementation of a 35-year DBFM P3 model in the healthcare sector. The project aims to meet the growing healthcare demands of the South Niagara region and has been

nominated for the ESG National Award category at the 2023 National P3 Awards [139]. This recognition highlights the project's innovative approach, sustainable design considerations, and positive community impact, including collaboration with indigenous stakeholders in project design [138]. The project team consists of Niagara Health, overseeing development and operations, Infrastructure Ontario managing project management, financing, and procurement, and EllisDon Corporation as the builder with Parkin Architects Ltd. and Adamson Associates Architects as the project architects and EllisDon Facilities Services as the service contractor [140].

4.2.1.2. Scope and Objectives of Niagara Health

The South Niagara Hospital project aimed to achieve three key objectives. Firstly, it aims to employ innovative designs and technology to prioritize sustainability and minimize environmental impact by efficiently using resources and adopting green building practices. The goal is to meet the LEED Silver standards set by the Canada Green Building Council and obtain WELL v2 certification [137] [141]. Secondly, it aims to involve the local community in the planning process to ensure the hospital meets their needs. Thirdly, the delivery of the project requires to collaborate with various stakeholders, including government bodies such as the ministry of health, community members, hospital staff, and partners, to ensure project success. Likewise, by opting for a DBFM model, the project’s value-for-money objective is to achieve 15% to 22% savings [141]. Table 18 below summarises the key objectives and the subsequent evaluative consideration used as reference during the subjective preference judgement of ESG weights.

Table 18. Key Objectives and Proposed ESG Evaluation Criteria for the Hospital Project

Objectives	ESG evaluative consideration for South Niagara project
Sustainability and environmental impact reduction	Environment: Comparing the extent to which the one P3 model encourages the private partner to invest in innovative technologies and sustainable practices that improve long-term performance and reduce environmental impact.
Community involvement in planning	Social: Community engagement and feedback mechanisms: Comparing the extent to which one P3 model facilitates meaningful community involvement in the planning, design, and decision-making processes related to the hospital project against the other. Social: Local benefit provision: Comparing how one P3 model ensures to deliver relevant community opportunities.
Stakeholder collaboration	Governance: Effective communication strategies: Comparing how one P3 model facilitates collaboration and engagement among diverse stakeholders including the hospital staff. Governance: Comparing how one P3 facilitate transparency and inclusivity of decision-making processes within the P3 framework considering early stakeholder engagement.
Financial savings	Value-for-money: Comparing the P3 model historical data on attaining value-for-money and long-term affordability including operational efficiency.

4.2.1.2 Application of AHP-PPP Selection Model

The AHP-PPP model is applied to the South Niagara Hospital project to compare and rank the available P3 model alternatives; DBFM, DBFOM, Progressive P3s, P3 Bundle model, based on how well they align with ESG evaluative criteria and value-for-money aspects. The main goal of the South Niagara Hospital project is environmental sustainability, aiming to reduce environmental impact by using resources efficiently and adopting green building practices. This is evident in the project's efforts to achieve two environmental building standards: the LEED Silver standards and WELL v2, showing a strong focus on environmental responsibility. While other objectives are important, they may not be as central as environmental sustainability. The WELL building standard version 2 is a recent building design standard that focus on design and

operational considerations that focus on human health and well-being [142]. Table 19 below shows the preference scale used as input = c, in the AHP-PPP excel tool with reference to the Saaty Fundamental scale and the generalised balanced n scale.

Table 19. Verbal Preference to Numerical Conversion Input (c) used in AHP-PPP Excel Tool

x	Verbal preference	Fundamental AHP Scale $C = x$	Generalised balanced (balanced n) $\left(C = \frac{9 + (n-1)\,x}{9 + n - x} \right)$ Where level 2, n=4 Level 3, n=5	
			n = 4	n = 5
1	Equal	1	1	1
2	Equal/Moderate	2	1.36	1.42
3	Moderate	3	1.8	1.91
4	Moderate/Strong	4	2.33	2.3
5	Strong	5	3	3.22
6	Strong/Very Strong	6	3.86	4.125
7	Very Strong	7	5	5.29
8	Very Strong/Extreme	8	6.6	6.83
9	Extreme	9	9	9

Tables 20 and 21 show the priority values of the criteria and the summarized alternative weights, respectively, comparing the results from the Fundamental AHP Scale and the Balanced-n scale.

Table 20. South Niagara Hospital: Local criteria priorities

		Fundamental AHP Scale	Balanced-n Scale n = 4	Differences (-/+)
1.	**Environmental**	**0.394 (39.4%)**	**0.432 (43.2%)**	**-0.038**
2.	Social	0.241	0.208	0.033
3.	Governance	0.167	0.172	-0.005
4.	Value-for-money	0.197	0.188	0.009
	Consistency Ratio	**0.02**	**0.006**	**0.014**

Both scales prioritize the environmental criterion as the most important consideration aligned with the project's objective. Likewise, the goal is to ensure that the decision support AHP-

PPP excel tool produce consistent and reliable results with low inconsistency value of less than 0.1, as indicated by the results the inconsistency value is less than 0.1. The difference between the two scales is also very minimal suggesting not much difference for results of the P3 model ranking considering a selection problem having four criteria. The priority values for the alternatives concerning each criterion are summarized in Table 22 and depicted in Figure 29 below

Table 21. South Niagara Hospital: Local alternative priorities with respect to each criterion

Fundamental AHP Scale	**Environmental**	**Social**	**Governance**	**Value-for-money**
DBFM	0.139	0.120	0.129	0.146
DBFMO	0.164	0.164	0.169	0.146
PR. DBFM	0.214	0.238	0.220	0.223
PR. DBFOM	**0.289**	**0.286**	**0.289**	**0.291**
P3 bundle	0.193	0.192	0.193	0.194
Consistency ratio	**0.049**	**0.06**	**0.05**	**0.033**
Balanced n Scale n = 5	**Environmental**	**Social**	**Governance**	**Value-for-money**
DBFM	0.137	0.137	0.129	0.142
DBFMO	0.180	0.180	0.190	0.206
PR. DBFM	0.203	0.231	0.217	0.183
PR. DBFOM	**0.286**	**0.254**	**0.269**	**0.272**
P3 bundle	0.195	0.197	0.195	0.197
Consistency ratio	**0.029**	**0.019**	**0.033**	**0.018**

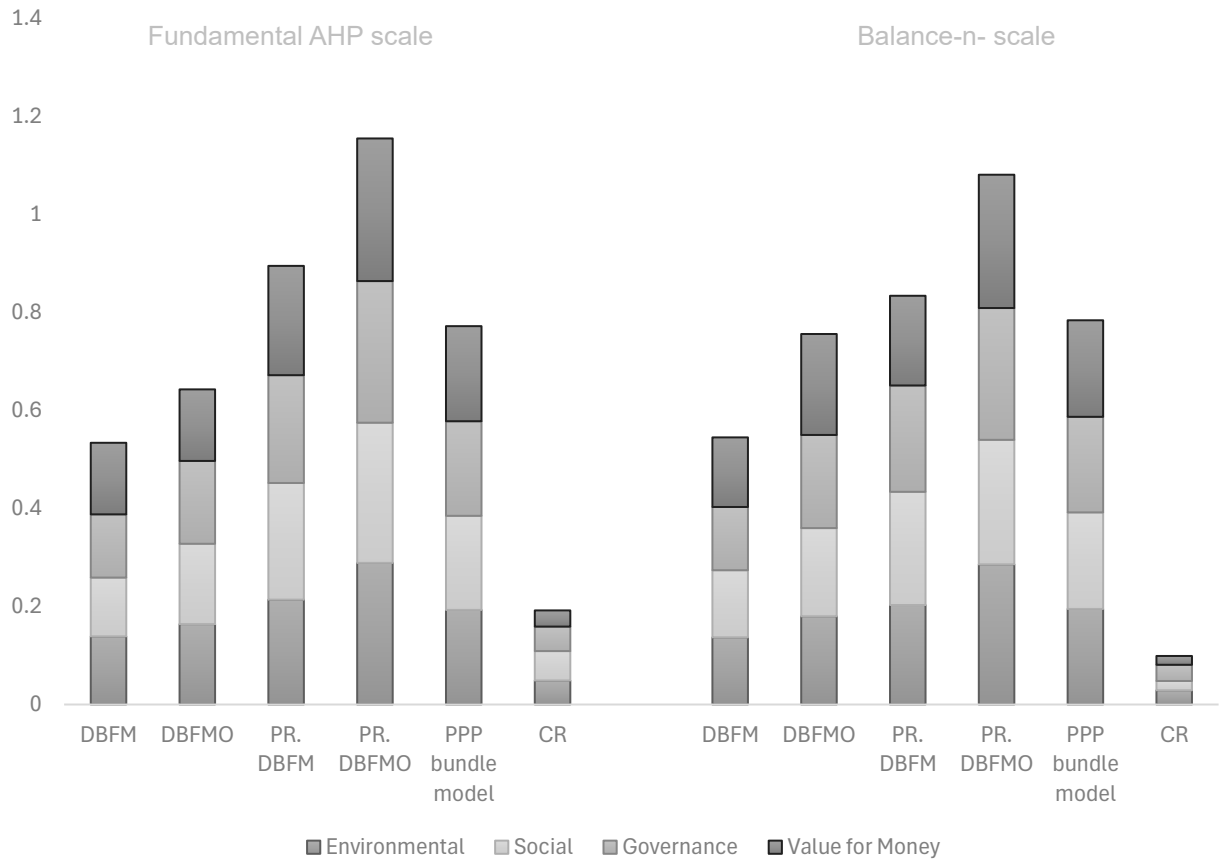


Figure 29. South Niagara Hospital: Priority weights of P3 models and each criterion

The final results for both the Fundamental AHP Scale and the balanced -n scale results analysis show that the Progressive DBFOM is the most suitable P3 model for the project as seen in Table 22 below. The project is being delivered using a DBFM model.

Table 22. South Niagara Hospital: Overall priority weights of P3 model option

P3 Alternative	Fundamental AHP scale	Balanced-n scale	Difference (+/-)
DBFM	0.130	0.137	-0.007
DBFMO	0.157	0.187	-0.03
PR. DBFM	0.216	0.207	0.009
PR. DBFOM	**0.280**	**0.274**	**0.006**
P3 bundle	0.187	0.196	-0.009

4.2.2. Case study 2: Finch West Light Rail Transit

4.2.2.1. Case Description

The Finch West LRT is a transit project situated in northwest Toronto, Ontario, spanning an 11-kilometre network with 18 stops. It includes the construction of key stations like the Humber College Station and Finch West Station, along with a 10,000 square foot storage and maintenance facility for the light rail vehicles [143]. Construction began in 2018 with an expected completion date in 2023. However, the project is still under construction and expected to complete in 2024 [144]. This serves as a significant case study highlighting schedule delays within a 35-year DBFM P3 model in the public transit sector. The project team includes the private sector entity, Mosaic Transit Group, chosen for their technical expertise, construction schedule, pricing, funding stability, and maintenance plans. Oversight during construction is provided by government agencies Metrolinx and Infrastructure Ontario on the public sector side. This project marks the second P3 social transit project to participate in Metrolinx's Community Benefits program, which is designed to offer economic opportunities, job training, and enhancements to the community [145].

4.2.2.2 Scope and Objectives of Finch West Light Rail Transit

The objectives of the Finch West Light Rail Transit project are to improve public transit, minimize community disruptions during construction, ensure high-quality design within budget and schedule, and maintain the system long-term [145]. All these goals are required by the project agreement [146] to consider environmental considerations verified by third-party certification. However, there is no available information regarding the specific level of LEED certification achieved. The project opted for a DBFM model; therefore, the project’s value-for-money objective is to achieve cost savings of up to 22.7%. However, due to the schedule delay of the DBFM model, the value-for-money may not have been fully met. On the other hand, participating in Metrolinx’s Community Benefits program highlights the importance of "community benefits" in alignment with

broader project community goals. Table 23 below summarises the key objectives and the subsequent ESG evaluative consideration used as reference during the subjective preference judgement of ESG weights.

Table 23. Key Objectives and Proposed ESG Evaluation Criteria for the Transit Project

Objectives	ESG evaluative consideration for South Niagara project
Reduce traffic carbon emissions	Environment: Comparing how different P3 models will provide better innovation and incentive for transit infrastructure performance, operational efficiency, and sustainability.
Align with broader social and economic goals	Social: Comparing how different P3 models affect social factors like creating local jobs, promoting social inclusion, ensuring equity, and fostering community development given their contractual arrangements and phase integration.
Stakeholder management	Governance: Comparing how one P3 facilitate transparency and inclusivity of decision-making processes within the P3 framework considering early stakeholder engagement.
Financial savings	Value-for-money: Comparing on P3 model historical data on attaining cost savings taking consideration of the identified schedule delays and cost overruns in Transit projects.

4.2.2.3. Application of AHP-PPP Selection Model

In a similar fashion as in the earlier case study. The importance of judgment for criteria with respect to the goal can be seen as a matrix as shown in the Table 24 below.

Table 24. Finch West Light Rail Transit: Local Criteria Priorities

		Fundamental AHP Scale	Balanced-n Scale	Differences (-/+)
1.	Environmental	0.351 (35.1%)	0.311 (31.1%)	0.04
2.	**Social**	**0.380 (38.0%)**	**0.329 (32.9%)**	0.051
3.	Governance	0.127 (12.7%)	0.172(16.5%)	-0.045
4.	Value-for-money	0.142(14.2%)	0.187 (14.8%)	-0.045
	Consistency Ratio	**0.06 (6%)**	**0.003 (0.3%)**	**0.057**

Both scales prioritize the social criterion and second the environmental criterion aligned with the ESG project's objective. The consistency ratios fall below the 0.1 threshold, indicating reliable consistency results. The priority values for the alternatives concerning each criterion are summarized in Table 25 and depicted in Figure 30 below.

Table 25. Finch West Light Rail Transit: Local Alternative Priority with respect to Each Criterion

Fundamental AHP Scale	**Environmental**	**Social**	**Governance**	**Value-for-money**
DBFM	0.129	0.138	0.153	0.147
DBFMO	0.169	0.169	0.226	0.147
PR. DBFM	0.220	0.278	0.197	0.254
PR. DBFOM	0.289	0.220	0.226	0.254
P3 bundle	0.193	0.195	0.197	0.197
Consistency Ratio	0.046	0.033	0.018	0.018
Balanced n Scale				
DBFM	0.161	0.163	0.174	0.172
DBFMO	0.185	0.184	0.214	0.172
PR. DBFM	0.212	0.243	0.199	0.228
PR. DBFOM	0.244	0.212	0.214	0.228
P3 bundle	0.198	0.198	0.199	0.199
Consistency Ratio	0.011	0.010	0.004	0.004

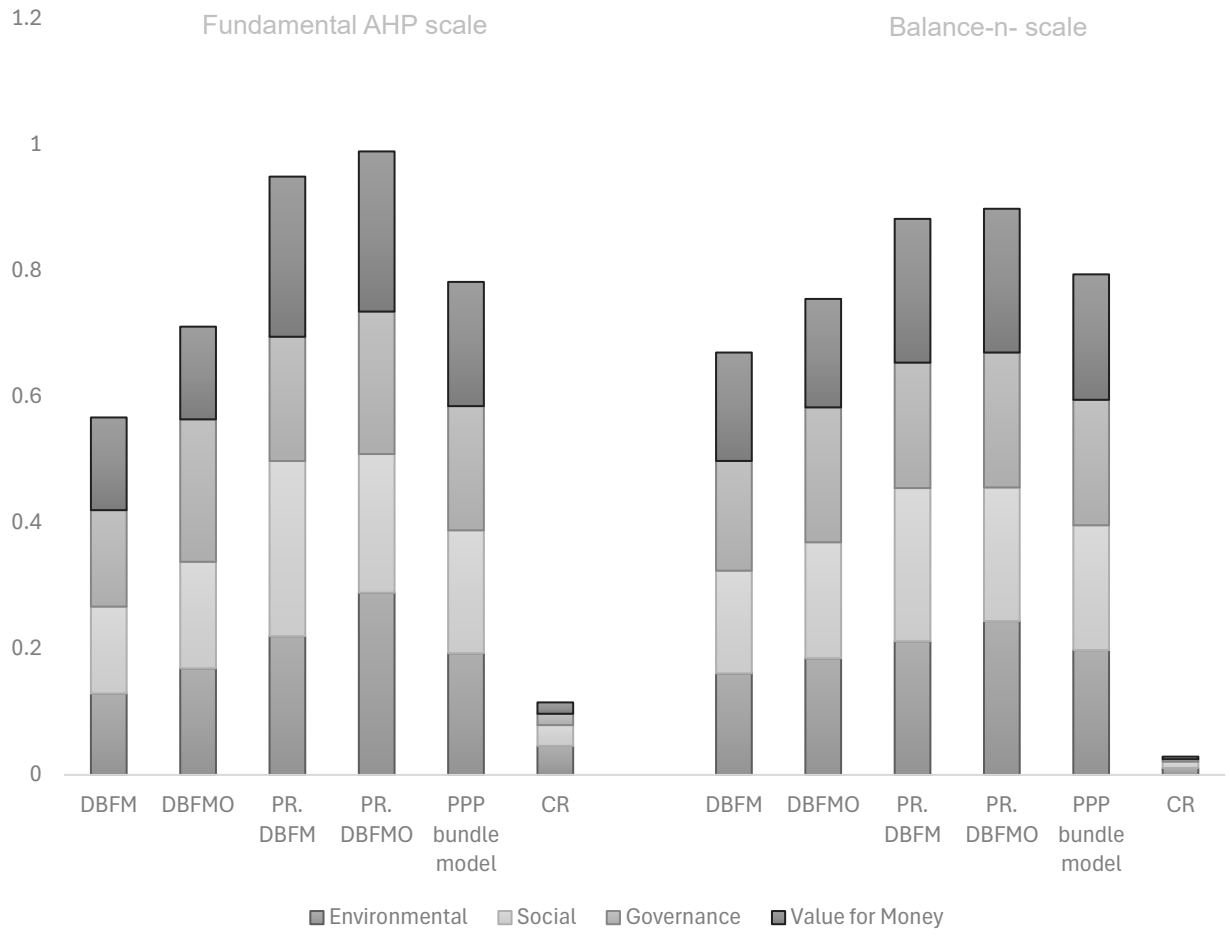


Figure 30. Finch West Light Rail Transit: Priority weights of P3 models and each criterion

The final results for the Fundamental AHP Scale and the balanced -n scale results analysis show that the PR. DBFOM is the most suitable P3 model for the project as seen in Table 26 below. The project is being delivered under a DBFM model.

Table 26. Finch West Light Rail Transit: Overall Priority weights of P3 model option

P3 Alternative	Fundamental AHP scale	Balanced-n scale	Differences
DBFM	0.138	0.166	-0.028
DBFMO	0.173	0.187	-0.014
PR. DBFM	0.244	0.223	0.021
PR. DBFOM	**0.250**	**0.225**	**0.025**
Alberta P3 model	0.195	0.198	-0.003

4.2.3. Case study 3: Saskatchewan Joint Use School Projects

4.2.3.1. Case Description

This project is the largest school project in Saskatchewan and was awarded the Silver Award for innovative Partnerships by CCPPP in 2015. It involves a 32-year DBFM agreement to construct 18 joint-use schools across 9 sites. Project 1 in Regina comprises three schools, while Project 2 covers four in Saskatoon, one in Warman, and one in Martensville. It is currently in its operation phase and was scheduled for completion in 2017. The value-for-money of the bundled DBFM was 13.5% of the total project cost, when compared to a conventional Design Build approach. The project team comprised of the Saskatchewan Ministry of Education as the public sector and Joint Use Mutual Partnership (JUMP) as the private sector [63].

4.2.3.2 Scope and Objectives of Saskatchewan Joint Use School Projects

The objectives of the Saskatchewan Joint Use School Projects are to deliver school buildings that provide conducive learning environments within budget and schedule. Likewise, managing a multi-site project with various stakeholders brings distinct challenges compared to a single-site project, requiring additional accountability and diligence for project agreement implementation [63]. Therefore, ensuring value-for-money and effective stakeholder management, including transparency and accountability, are the most important objectives given the nature of the project. Similarly, engaging with various school boards is important for project success, spanning from initial planning to execution, maintenance, and operation. On the other hand, although there's no formal commitment to a CBA, the projects observed engaging local businesses for economic benefits [63]. The environmental criterion was considered through the silver LEED certification that was to be achieved. The Table 27 below summarises the key objectives and the subsequent ESG evaluative consideration.

Table 27. Key objectives and ESG consideration for Saskatchewan Joint Use School Projects.

Objectives	ESG and VfM considerations
Multi-site project agreement implementation	Governance: Compares how a P3 model addresses the challenges of managing a multi-site project with diverse stakeholders, ensuring effective communication, oversight, and adherence to project objectives.
Financial savings	Value-for-money: Compares historical data on the P3 model capacity to deliver value-for-money over the project's lifecycle.
Community benefits	Social: Compares how a P3 model will engage with local communities for design inputs and feedback.
Building quality and comfort design	Environmental: Compares how different green design consideration will be engaged in different phases.

4.2.3.3. Application of AHP-PPP Selection Model

The priority values for each criterion's alternatives are summarized in Tables 28 and 29 and depicted in Figure 31 below. The final results for the Fundamental AHP Scale and the balanced -n scale results analysis show that the PR. DBFOM is the most suitable P3 model for the project as seen in Table 30 below. The project was delivered under a DBFM bundle model.

Table 28. Saskatchewan Joint Use School Projects: Local criteria priorities

		Fundamental AHP Scale	Balanced-n Scale	Differences (-/+)
1.	Environmental	0.149	0.187	-0.038
2.	Social	0.233	0.225	0.008
3.	**Governance**	**0.377**	**0.343**	0.034
4.	Value-for-money	0.241	0.245	-0.004
	Consistency Ratio	0.046	0.022	0.024

Table 29. Saskatchewan Joint Use School Projects: Local alternative priorities with respect to each criterion.

Fundamental AHP Scale	Environmental	Social	Governance	Value-for-money
DBFM	0.104	0.128	0.089	0.082
DBFMO	0.141	0.171	0.133	0.137
PR. DBFM	0.230	0.252	0.295	0.137
PR. DBFOM	0.182	0.161	0.179	0.227
P3 bundle model	0.343	0.372	0.388	0.417
Consistency ratio	0.025	0.014	0.006	0.012
Balanced n Scale				
DBFM	0.141	0.160	0.132	0.122
DBFMO	0.170	0.160	0.182	0.165
PR. DBFM	0.222	0.209	0.193	0.165
PR. DBFOM	0.194	0.182	0.193	0.218
Bundle P3 model	0.273	0.290	0.299	0.331
Consistency ratio	0.007	0.004	0.002	0.005

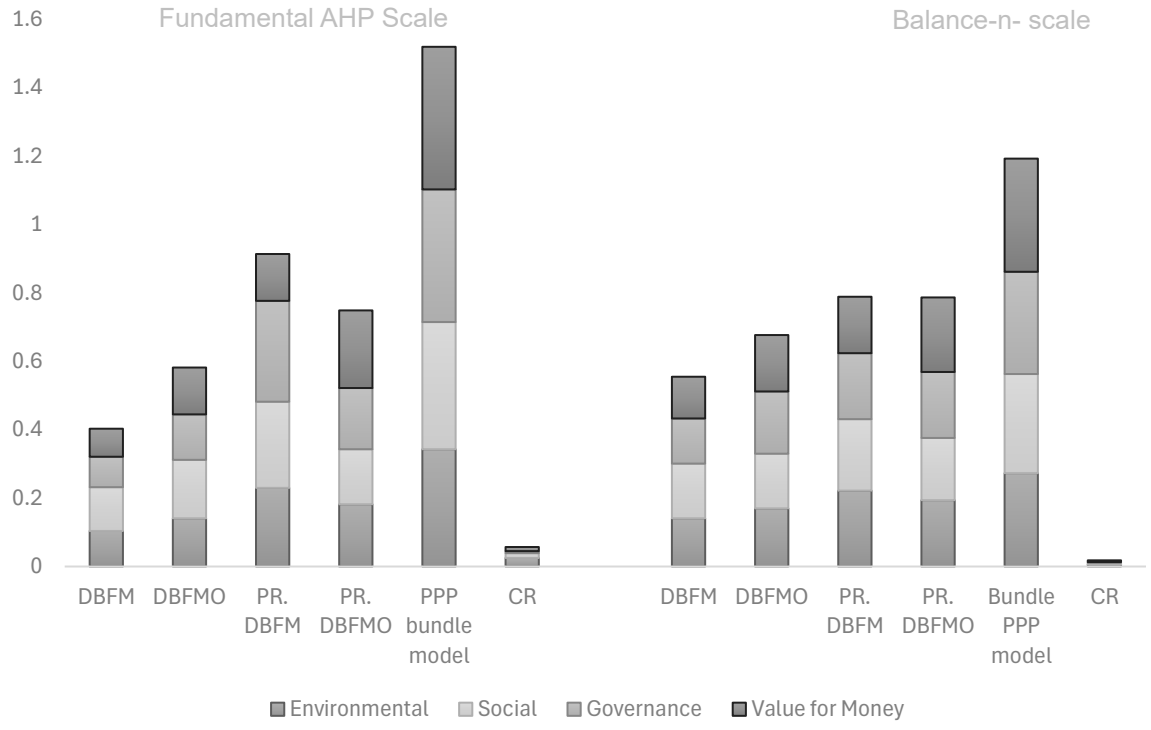


Figure 31. Saskatchewan Joint Use School Projects: Priority weights of P3 models and each criterion

Table 30. Saskatchewan Joint Use School Projects: Overall priority weights of P3 model option

P3 Alternative	Fundamental AHP Scale	Balanced-n scale	Difference (-/+)
DBFM	0.099	0.138	-0.039
DBFMO	0.146	0.171	-0.025
PR. DBFM	0.184	0.195	-0.011
PR. DBFOM	0.187	0.197	-0.01
P3 bundle model	**0.385**	**0.300**	**0.085**

4.3. Analysis and Discussion

For Case 1, The South Niagara Hospital, the decision of the AHP-PPP model favored the Progressive DBFOM, as indicated in Table 22 above. The operational phase and the progressive procurement approach are expected to yield better outcomes in mitigating the environmental footprint and ensuring sustainable operations of the hospital, given the increased incentives for the private sector. This aligns with the key challenge and ESG objectives specific to hospitals identified in the literature, particularly focusing on improving operational efficiency. Additionally, in 2023, two hospital projects in Ontario were procured using the progressive DBFM model, indicating a preference for this model in delivering hospital project. However, the assessment of the progressive DBFM may have inadequately addressed ESG concerns and challenges.

For Case 2, the Finch west LRT, the decision of the AHP-PPP model favored the progressive DBFOM, as seen in Table 26 above. This decision aligns with the prevalent use of the progressive model for procuring transit-oriented projects in Ontario and the findings of the literature review that identified key challenges and objectives for transit projects, including the lack of consistent operational funding and the need for more reliable and sustained lifecycle funding, respectively. The operational phase of the DBFOM model will offer the public sector reliability in project funding from the private sector, potentially supporting the government during operation. Furthermore, the progressive procurement strategy aligns with the evidence-based decision-making objectives of

transit project implementation by ensuring early involvement of different stakeholders in project planning for more objective decision-making. However, the project was procured using the DBFM, with a primary focus on community benefits as the most critical criterion.

For Case 3, the Saskatchewan Joint Use School Projects, The AHP-PPP model's decision favored the P3 bundle model, as demonstrated in Table 30 above. This is consistent with the P3 bundle procurement approach adopted for this project, aimed at addressing the operational challenges outlined in Table 3. The progressive DBFM bundle emerges as the preferred choice. However, the progressive DBFOM bundle could also be considered, with the project team needing to involve school boards in the administrative operational team to ensure flexibility in managing the schools.

The historical data on the value-for-money of various Canadian P3 models, including DBFM, DBFMO, Progressive DBFM, Progressive DBFOM, and the P3 bundle model, along with the identified ESG project objectives documented in the case descriptions served as a useful guide for subjective preferences when making pairwise comparisons between these models for each case study. The results shows that the generalized balanced scale exhibits greater consistency and reliability when assessing P3 suitability for sustainable and responsible outcomes. Furthermore, the decision outcomes regarding P3 model selection remained consistent across all case studies for both scales, despite variations in criteria weight distribution, as observed by Goepel [135]. This indicates that both scales are dependable as long as decision makers refine their judgments to accurately reflect the relative importance of P3 alternatives. A sensitivity analysis, conducted using an AHP sensitivity analysis tool, revealed changes in rankings for the third and fourth alternatives maintaining the first rank for the first P3 model of the hospital and school projects. This indicates reliable decision-making unaffected by minor variations in criteria weights. As for the transit project the ranking of the first results changes with varying weight preferences (see appendix IV).

Chapter 5: Conclusion and Recommendations

5.1. Conclusion

This thesis addressed the required shift in the screening of P3 social infrastructure projects in Canada. First, it identified existing qualitative P3 procurement evaluative criteria, which currently focus on six groups of criteria related to project characteristics, scope, cost, historical considerations, contract components, risk, and market capacity factors. While these criteria are effective for delivering some social infrastructure project objectives, there is a comprehensive need for addressing non-financial aspects that evaluate responsible practices and sustainability principles, to evaluate environmental and social impacts and align with Canada's commitment to delivering more sustainable and responsible infrastructure projects. Consequently, relevant ESG procurement objectives of social infrastructure projects were identified and defined to screen for a P3 model.

The specific ESG criteria identified for Canada cover various dimensions. Under environmental considerations, the criteria include green adoption incentives and life-cycle assessment. In addressing social aspects, the focus was on community benefits, including assessments of community impact phases and levels of community engagement. In terms of governance, stakeholder engagement criteria emphasized transparency and accountability. These criteria were then incorporated into the existing two-stage procurement process to evaluate the potential of P3 models in promoting sustainable and responsible practices within social infrastructure projects.

For the first stage of the procurement process, where a screening matrix is used to determine whether the project has the potential to be carried out as a P3 project. This thesis successfully developed a practical screening assessment form which is known as the P3-ESG suitability screening matrix. It will assess both traditional project delivery models like DBB, DB and

DBF models against the P3 model in attaining responsible sustainability for the project. It will also screen for a satisfactory level to opt for a P3 model in align with environmental, social, and governance goals of social infrastructure project. For every ESG criterion, a response indicator, the description, and measured question is provided as seen on appendix II. Once the social infrastructure project is considered suitable for a P3 model to achieve responsible sustainability, the most suitable type of P3 model is determined during the second stage of the procurement process.

In the second stage of the procurement process, this thesis developed a multi-criteria analysis tool, an AHP-PPP model, to aid in selecting the best P3 alternative model by integrating both quantitative and qualitative criteria in the evaluation. Only primary, mutually independent ESG criteria and VfM were considered for assessment to prevent potential inconsistencies arising from interdependent sub-criteria in the P3-ESG screening matrix. The effectiveness of the AHP-PPP model in practical applications has been demonstrated through real-life case studies where a comparative AHP-scale study was conducted using two AHP scales for pairwise comparison. The results remained consistent for both the fundamental AHP scale and the balanced-n scale, regardless of the presence of unequal weight distribution when comparing options with close preferences for more than two criteria, as suggested by Goepel [135].

The results of this proposed AHP-PPP model will depend on expertise and skills of the decision-making team and the specific ESG goals of each social infrastructure project. These factors will influence the preferences and decisions generated by the AHP-PPP model. Similarly, when applying the AHP-PPP model to projects, there is a lack of historical data to inform decisions for the progressive P3 model. This absence of past performance information poses a challenge in accurately assessing the significance of each ESG criterion. As a result, preference scoring from the input value from 1 to 9 relied more heavily on predictions and informed assumptions.

In conclusion, this thesis introduces a new approach to procuring sustainable P3 models by integrating non-financial ESG factors into P3 project screening and P3 model selection. Achieving a more environmentally and socially conscious Canada relies on successfully delivering sustainable social infrastructure projects, as they constitute the largest type of infrastructure projects delivered in Canada using P3 models. The thesis emphasizes evaluating P3 models as tools for responsible sustainability from the planning stage of P3 project procurement. It addresses the balanced need to think about social and environmental factors alongside financial considerations when evaluating P3 models. The achieved research objectives align with current demands for sustainable infrastructure development, contributing to societal benefits, environmental well-being, and a more responsible future for Canada's social infrastructure projects.

5.2. Recommendations

The following is a list of future research directions:

1. Explore incorporating potential risks into the AHP-PPP model, including understanding how to assign importance to the identified ESG risks.
2. Apply the P3-ESG screening matrix for indigenous social infrastructure P3 projects on reserve lands to identify their context-specific ESG considerations.
3. Conduct case studies on sustainable and responsible performance of progressive P3 models currently procured for transit and hospital projects to assist decision makers in making informed relative comparison of the progressive P3 models to other P3 models when using the AHP-PPP model.

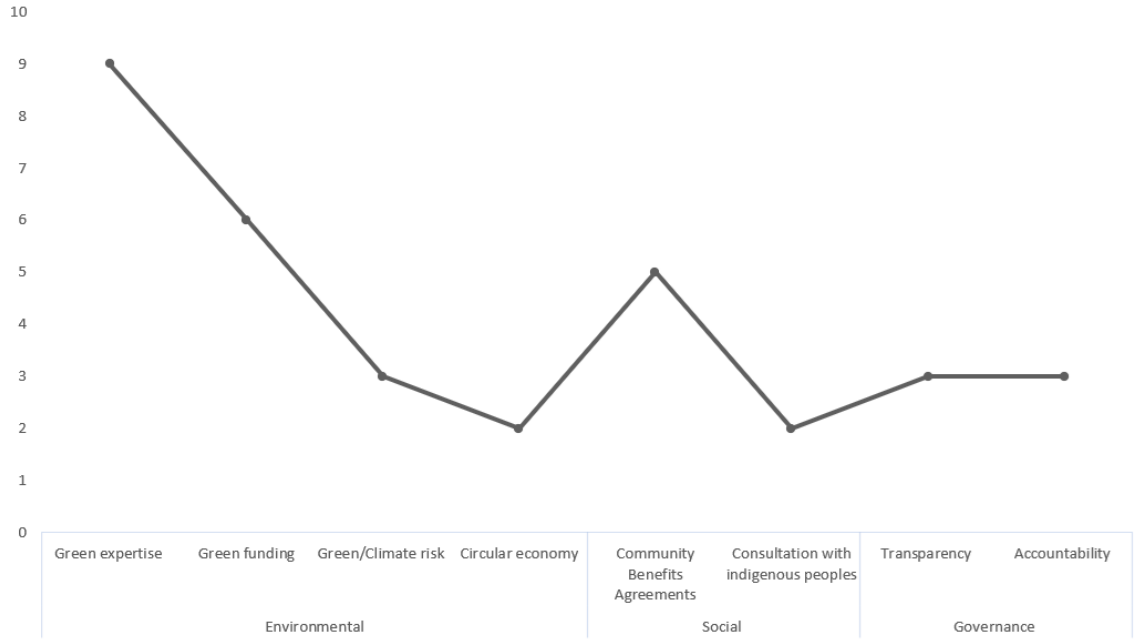
These recommendations would contribute further to developing a relevant industry standard ESG-PPP decision-making framework, acknowledging the evolving dynamics of P3 projects and ESG considerations in different context, and promoting sustainable infrastructure development in Canada.

Appendix I

Sub-Criteria Selection (based on literature review)

The sub-criteria used for the screening matrix were selected according to the highest number of occurrences in the literature reviewed. To ensure the matrix is not exhausted with a lot of redundant sub-criteria only two were selected for each dimension. Therefore, the assessment focused on evaluating "green-related risks" and "green-adapted processes" within the broader process of forming green expertise partnerships.

Criteria	Proposed extrapolation of sub-criteria in relevance to project management and identified objectives and challenges in social infrastructure	Frequency of occurrence	No. of Occurrences
Environmental	Green expertise partnership	[114] [91] [52] [13] [30] [39] [147] [63] [112]	**9**
	Green funding	[148] [115] [50] [48] [116] [149]	**6**
	Green (climate) risk	[150] [151] [152]	3
	Circular economy: Green adapted processes	[116] [153]	2
Social	Community benefits agreements	[1] [63] [43] [94] [51]	**5**
	Consultation with indigenous peoples	[111] [152]	2
Governance	Transparency	[16] [49] [78]	**3**
	Accountability		



Appendix II

Screening Matrix form

Criteria 1: Environmental: Green adoption incentives How does the P3 model incentivize and adopt environmentally friendly practices, technologies, and standards?							
What is being measured?	**Green expertise partnership:** The level of green expertise and sustainability knowledge possessed by the private sector partner. This includes evaluating their track record in implementing environmentally friendly practices and their capacity to innovate in sustainable technologies and solutions.						Weighting 16.7%
	Question asked?	Are there any partnerships or collaborations with environmental organizations or experts to leverage expertise and best practices in project sustainability?					
		1	2	3	4	5	
	Indicator:	No green expertise	Limited green expertise	Moderate green expertise	Substantial green expertise	High green expertise	
What is being measured?	**Green funding:** The flexibility in financial partnership, allowing for the incorporation of green financing mechanisms such as green bonds, sustainability-linked loans, or performance-based contracts.						Weighting 16.7%
	Question asked?	Does the P3 model have environmental conscious funding options, like green bonds or sustainability-linked loans?					
		1	2	3	4	5	
	Indicator:	No Green Funding	Limited Green Funding	Partial Green Funding	Moderate Green Funding	High Green Funding	

Criteria 2: Social: Community benefits: Community Impact Phases and Community engagement How does the P3 model influence the nature and scope of community benefits agreements, emphasizing and prioritizing immediate gains or long-term sustainability and if they are developed collaboratively with community stakeholders including local SMEs?							
What is being measured?	**Long-Term CBA**: Duration of community benefits for non-core services, focusing on long-term social benefit engagement.						Weighting 16.7%
	Question asked?	Does the PPP model involve long-term integration of community benefits?					
		1	2	3	4	5	
	Indicator:	No Integration	Limited Integration	Partial Integration	Moderate Integration	High Integration	
What is being measured?	**Collaborative CBA:** Level of collaboration with community stakeholders in developing CBAs.						Weighting 16.7%
	Question asked?	How does the P3 model ensure the CBA have feedback from the community?					
		1	2	3	4	5	
	Indicator:	No Community feedback	Limited feedback	Partial feedback	Moderate feedback	High feedback	

Criteria 3: Governance: Stakeholder engagement: Transparency and Accountability How does the P3 model influence the overall structure of decision-making processes within the project team and other stakeholders, involving the formulation, discussion, communication, finalization, and implementation of project agreements?							
What is being measured?	**Transparency**: Level of transparency in P3 model through early engagement, communication channels, decision-making structure, and long-term stakeholder management						Weighting 16.7%
	Question asked?	How does the P3 models ensure stakeholder engagement in different phases of the project?					
		1	2	3	4	5	
	Indicator:	No Transparency	Limited Transparency	Partial Transparency	Moderate Transparency	High Transparency throughout project life cycle	
What is being measured?	**Accountability:** The degree of consistency in meeting project milestones and financial targets. How will project team take responsibility for achieving set goals and objectives.						Weighting 16.7%
	Question asked?	How consistently does the P3 model meet project environmental, social objectives and financial targets, demonstrating a high level of accountability?					
		1	2	3	4	5	
	Indicator:	No Accountability	Limited Accountability	Partial Accountability	Moderate Accountability	High Accountability	

Appendix III

AHP-PPP Excel tool

South Niagara Hospital – Pairwise Comparisons

To choose the preference judgment for comparing the criteria at level 2 of the hierarchy structure, the Excel tool provides a dropdown list of input scales

A. SAATY SCALE: Drop down list of values: 1,2,3,4,5,6,7,8,9

Level 2:

	Enviromental	Social	Governance	Value for Money
Enviromental	1	2	2	2
Social	0.5	1	2	1
Governance	0.5	0.5	1	1
Value for money	0.5	1	1	1
Sum	2.5	4.5	6	5

Normalized			
0.4	0.444444	0.333333	0.4
0.2	0.222222	0.333333	0.2
0.2	0.111111	0.166667	0.2
0.2	0.222222	0.166667	0.2

PV	Criteria weights
0.394	
0.239	
0.169	
0.197	

		Consistency
4.064	0.021	0.024

For this case, the environmental is considered to be two times important compared to the social criterion this indicates it is moderately important compared to the social, governance and value for money criterion.

B. BALANCED- N SCALE: The drop-down list of values includes: 1,1.36,1.8, 2.33, 3, 3.86, 5, 6.6, 9. This scale input, as indicated by the formula in Table 17 above, accounts for the number of criteria being compared, which in this case is 4 at level 2

	Enviromental	Social	Governance	Value for money
Enviromental	1	1.36	1.36	1.36
Social	0.735294118	1	1.8	1
Governance	0.735294118	0.555555556	1	1
Value for money	0.735294118	1	1	1
Sum	3.205882353	3.915555556	5.16	4.36

Normalized			
0.311927	0.347333	0.263566	0.311927
0.229358	0.255392	0.348837	0.229358
0.229358	0.141884	0.193798	0.229358
0.229358	0.255392	0.193798	0.229358

PV	Criteria weights
0.309	
0.266	
0.199	
0.227	

		Consistency
4.045	0.015	0.016

Likewise, using the balanced-n scale, the environmental is considered to be two 1.36 times important compared to the social criterion this indicates it is moderately important compared to the social, governance and value for money criterion.

A. SAATY SCALE: Level 3: Alternative pairwise comparison

Environmental	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.3333333	0.5	1
DBFMO	1	1	1	0.5	1
PR.DBFM	3	1	1	0.5	1
PR.DBFMO	2	2	2	1	1
PPP bundle model	1	1	1	1	1
Sum	8	6	5.3333333	3.5	5

Normalized				
0.125	0.166667	0.0625	0.142857	0.2
0.125	0.166667	0.1875	0.142857	0.2
0.375	0.166667	0.1875	0.142857	0.2
0.25	0.333333	0.375	0.285714	0.2
0.125	0.166667	0.1875	0.285714	0.2

PV	Criteria weights
0.139	
0.164	
0.214	
0.289	
0.193	

Consistency
0.049302

Social	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.5	0.3333333	0.5	1
DBFMO	2	1	0.5	0.5	1
PR.DBFM	3	2	1	0.5	1
PR.DBFMO	2	2	2	1	1
PPP bundle model	1	1	1	1	1
Sum	9	6.5	4.8333333	3.5	5

Normalized				
0.111111	0.076923	0.068966	0.142857	0.2
0.222222	0.153846	0.103448	0.142857	0.2
0.333333	0.307692	0.206897	0.142857	0.2
0.222222	0.307692	0.413793	0.285714	0.2
0.111111	0.153846	0.206897	0.285714	0.2

PV	Criteria weights
0.120	
0.164	
0.238	
0.286	
0.192	

Consistency
0.057607

Governance	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.5	0.5	0.5	1
DBFMO	2	1	0.5	0.5	1
PR.DBFM	2	2	1	0.5	1
PR.DBFMO	2	2	2	1	1
PPP bundle model	1	1	1	1	1
Sum	8	6.5	5	3.5	5

Normalized				
0.125	0.076923	0.1	0.142857	0.2
0.25	0.153846	0.1	0.142857	0.2
0.25	0.307692	0.2	0.142857	0.2
0.25	0.307692	0.4	0.285714	0.2
0.125	0.153846	0.2	0.285714	0.2

PV	Criteria weights
0.129	
0.169	
0.220	
0.289	
0.193	

Consistenecy: 0.046397

Value for money	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.5	0.5	1
DBFMO	1	1	0.5	0.5	1
PR.DBFM	2	2	1	0.5	1
PR.DBFMO	2	2	2	1	1
PPP bundle model	1	1	1	1	1
Sum	7	7	5	3.5	5

Normalized				
0.142857	0.142857	0.1	0.142857	0.2
0.142857	0.142857	0.1	0.142857	0.2
0.285714	0.285714	0.2	0.142857	0.2
0.285714	0.285714	0.4	0.285714	0.2
0.142857	0.142857	0.2	0.285714	0.2

PV	Criteria weights
0.146	
0.146	
0.223	
0.291	
0.194	

Consistenecy: 0.032526

B. BALANCED – N SCALE: Level 3: Alternative pairwise comparison: The drop-down list of values includes: 1, 1.42, 1.91, 2.3, 3.22, 4.125, 5.29, 6.83, and 9. This scale input, as indicated by the formula in Table 17 above, accounts for the number of criteria being compared, which in this case is 5 at level 3

Environmetal	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.704225352	0.434782609	0.523560209	1
DBFMO	1.42	1	1	0.523560209	1
PR.DBFM	2.3	1	1	0.523560209	1
PR.DBFMO	1.91	1.91	1.91	1	1
PPP bundle model	1	1	1	1	1
Sum	7.63	5.614225352	5.344782609	3.570680628	5

Normalized				
0.131062	0.125436	0.081347	0.146628	0.2
0.186107	0.178119	0.187098	0.146628	0.2
0.301442	0.178119	0.187098	0.146628	0.2
0.250328	0.340207	0.357358	0.280059	0.2
0.131062	0.178119	0.187098	0.280059	0.2

PV	Criteria weights
0.137	
0.180	
0.203	
0.286	
0.195	

Consistenecy: 0.029

Social	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.704225352	0.434782609	0.523560209	1
DBFMO	1.42	1	0.704225352	0.704225352	1
PR.DBFM	2.3	1.42	1	0.704225352	1
PR.DBFMO	1.91	1.42	1.42	1	1
PPP bundle model	1	1	1	1	1
Sum	7.63	5.544225352	4.559007961	3.932010914	5

Normalized				
0.131062	0.12702	0.095368	0.133153	0.2
0.186107	0.180368	0.154469	0.179101	0.2
0.301442	0.256122	0.219346	0.179101	0.2
0.250328	0.256122	0.311471	0.254323	0.2
0.131062	0.180368	0.219346	0.254323	0.2

PV	Criteria weights
0.137	
0.180	
0.231	
0.254	
0.197	

Consistenecy: 0.019

Governance	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.523560209	0.434782609	0.523560209	1
DBFMO	1.91	1	0.704225352	0.704225352	1
PR.DBFM	2.3	1.42	1	0.523560209	1
PR.DBFMO	1.91	1.42	1.91	1	1
PPP bundle model	1	1	1	1	1
Sum	8.12	5.363560209	5.049007961	3.751345771	5

Normalized				
0.123153	0.097614	0.086112	0.139566	0.2
0.235222	0.186443	0.139478	0.187726	0.2
0.283251	0.26475	0.198059	0.139566	0.2
0.235222	0.26475	0.378292	0.266571	0.2
0.123153	0.186443	0.198059	0.266571	0.2

PV	Criteria weights
0.129	
0.190	
0.217	
0.269	
0.195	

Consistenecy: 0.033

Value for money	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.523560209	0.704225352	0.523560209	1
DBFMO	1.91	1	1	0.704225352	1
PR.DBFM	1.42	1	1	0.523560209	1
PR.DBFMO	1.91	1.42	1.91	1	1
PPP bundle model	1	1	1	1	1
Sum	7.24	4.943560209	5.614225352	3.751345771	5

Normalized				
0.138122	0.105908	0.125436	0.139566	0.2
0.263812	0.202283	0.178119	0.187726	0.2
0.196133	0.202283	0.178119	0.139566	0.2
0.263812	0.287242	0.340207	0.266571	0.2
0.138122	0.202283	0.178119	0.266571	0.2

PV	Criteria weights
0.142	
0.206	
0.183	
0.272	
0.197	

Consistenecy: 0.018

Finch West Light Rail Transit – Pairwise comparison

A. SAATY SCALE: Level 2

	Enviromental	Social	Governance	Value for Money
Enviromental	1	1	3	2
Social	1	1	3	3
Governance	0.333333333	0.333333333	1	1
Value for money	0.5	0.333333333	1	1
Sum	2.833333333	2.666666667	8	7

Normalized			
0.352941	0.375	0.375	0.285714
0.352941	0.375	0.375	0.428571
0.117647	0.125	0.125	0.142857
0.176471	0.125	0.125	0.142857

PV	Criteria weights
0.347	
0.383	
0.128	
0.142	

Consistenecy

4.022 0.007 0.008

B. BALANCED-N SCALE: Level 2

	Enviromental	Social	Governance	Value for money
Enviromental	1	1	1.8	1.36
Social	1	1	1.8	1.8
Governance	0.555555556	0.555555556	1	1
Value for money	0.735294118	0.555555556	1	1
Sum	3.290849673	3.111111111	5.6	5.16

Normalized			
0.303873	0.321429	0.321429	0.263566
0.303873	0.321429	0.321429	0.348837
0.168818	0.178571	0.178571	0.193798
0.223436	0.178571	0.178571	0.193798

PV	Criteria weights
0.303	
0.324	
0.180	
0.194	

		Consistency
4.010	0.003	0.004

A. SAATY SCALE: Level 3

Enviromental	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.5	0.5	0.5	1
DBFMO	2	1	0.5	0.5	1
PR.DBFM	2	2	1	0.5	1
PR.DBFMO	2	2	2	1	1
PPP bundle model	1	1	1	1	1
Sum	8	6.5	5	3.5	5

Normalized				
0.125	0.076923	0.1	0.142857	0.2
0.25	0.153846	0.1	0.142857	0.2
0.25	0.307692	0.2	0.142857	0.2
0.25	0.307692	0.4	0.285714	0.2
0.125	0.153846	0.2	0.285714	0.2

PV	Criteria weights
0.129	
0.169	
0.220	
0.289	
0.193	

		Consistency
5.207857	0.051964	0.046

Social	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.3333333	0.5	1
DBFMO	1	1	0.5	1	1
PR.DBFM	3	2	1	1	1
PR.DBFMO	2	1	1	1	1
PPP bundle model	1	1	1	1	1
Sum	8	6	3.8333333	4.5	5

Normalized				
0.125	0.166667	0.086957	0.111111	0.2
0.125	0.166667	0.130435	0.222222	0.2
0.375	0.333333	0.26087	0.222222	0.2
0.25	0.166667	0.26087	0.222222	0.2
0.125	0.166667	0.26087	0.222222	0.2

PV	Criteria weights
0.138	
0.169	
0.278	
0.220	
0.195	

		Consistency
5.148064	0.037016	0.033

Governance	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.5	1	0.5	1
DBFMO	2	1	1	1	1
PR.DBFM	1	1	1	1	1
PR.DBFMO	2	1	1	1	1
PPP bundle model	1	1	1	1	1
Sum	7	4.5	5	4.5	5

Normalized				
0.142857	0.111111	0.2	0.111111	0.2
0.285714	0.222222	0.2	0.222222	0.2
0.142857	0.222222	0.2	0.222222	0.2
0.285714	0.222222	0.2	0.222222	0.2
0.142857	0.222222	0.2	0.222222	0.2

PV	Criteria weights
0.153	
0.226	
0.197	
0.226	
0.197	

		Consistency
5.08	0.02	0.018

Value for Money	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.5	0.5	1
DBFMO	1	1	0.5	0.5	1
PR.DBFM	2	2	1	1	1
PR.DBFMO	2	2	1	1	1
PPP bundle model	1	1	1	1	1
Sum	7	7	4	4	5

Normalized				
0.142857	0.142857	0.125	0.125	0.2
0.142857	0.142857	0.125	0.125	0.2
0.285714	0.285714	0.25	0.25	0.2
0.285714	0.285714	0.25	0.25	0.2
0.142857	0.142857	0.25	0.25	0.2

PV	Criteria weights
0.147	
0.147	
0.254	
0.254	
0.197	

		Consistency
5.08	0.02	0.018

A. BALANCED-N SCALE: Level 3

Enviromental	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.704225352	0.704225352	0.704225352	1
DBFMO	1.42	1	0.704225352	0.704225352	1
PR.DBFM	1.42	1.42	1	0.704225352	1
PR.DBFMO	1.42	1.42	1.42	1	1
PPP bundle model	1	1	1	1	1
Sum	6.26	5.544225352	4.828450704	4.112676056	5

Normalized				
0.159744	0.12702	0.145849	0.171233	0.2
0.226837	0.180368	0.145849	0.171233	0.2
0.226837	0.256122	0.207106	0.171233	0.2
0.226837	0.256122	0.29409	0.243151	0.2
0.159744	0.180368	0.207106	0.243151	0.2

PV	Criteria weights
0.161	
0.185	
0.212	
0.244	
0.198	

		Consistency
5.050	0.013	0.011

Social	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.523560209	0.704225352	1
DBFMO	1	1	0.704225352	1	1
PR.DBFM	1.91	1.42	1	1	1
PR.DBFMO	1.42	1	1	1	1
PPP bundle model	1	1	1	1	1
Sum	6.33	5.42	4.227785562	4.704225352	5

Normalized				
0.157978	0.184502	0.123838	0.149701	0.2
0.157978	0.184502	0.166571	0.212575	0.2
0.301738	0.261993	0.23653	0.212575	0.2
0.224329	0.184502	0.23653	0.212575	0.2
0.157978	0.184502	0.23653	0.212575	0.2

PV	Criteria weights
0.163	
0.184	
0.243	
0.212	
0.198	

		Consistency
5.045	0.011	0.010

Governance	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.704225352	1	0.704225352	1
DBFMO	1.42	1	1	1	1
PR.DBFM	1	1	1	1	1
PR.DBFMO	1.42	1	1	1	1
PPP bundle model	1	1	1	1	1
Sum	5.84	4.704225352	5	4.704225352	5

Normalized				
0.171233	0.149701	0.2	0.149701	0.2
0.243151	0.212575	0.2	0.212575	0.2
0.171233	0.212575	0.2	0.212575	0.2
0.243151	0.212575	0.2	0.212575	0.2
0.171233	0.212575	0.2	0.212575	0.2

PV	Criteria weights
0.174	
0.214	
0.199	
0.214	
0.199	

		Consistency
5.020	0.005	0.004

Value for Money	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.704225352	0.704225352	1
DBFMO	1	1	0.704225352	0.704225352	1
PR.DBFM	1.42	1.42	1	1	1
PR.DBFMO	1.42	1.42	1	1	1
PPP bundle model	1	1	1	1	1
Sum	5.84	5.84	4.408450704	4.408450704	5

Normalized				
0.171233	0.171233	0.159744	0.159744	0.2
0.171233	0.171233	0.159744	0.159744	0.2
0.243151	0.243151	0.226837	0.226837	0.2
0.243151	0.243151	0.226837	0.226837	0.2
0.171233	0.171233	0.226837	0.226837	0.2

PV	Criteria weights
0.172	
0.172	
0.228	
0.228	
0.199	

Consistenecy

5.020 0.005 0.004

Saskatchewan Joint Use School Projects – Pairwise comparison.

A. SAATY SCALE: Level 2

	Enviromental	Social	Governance	Value for Money
Enviromental	1	0.5	0.333333333	1
Social	2	1	0.5	1
Governance	3	2	1	1
Value for money	1	1	1	1
Sum	7	4.5	2.833333333	4

Normalized			
0.142857	0.111111	0.117647	0.25
0.285714	0.222222	0.176471	0.25
0.428571	0.444444	0.352941	0.25
0.142857	0.222222	0.352941	0.25

PV	Criteria weights
0.149	
0.233	
0.377	
0.241	

Consistenecy

4.124 0.041 0.046

B. BALANCED-N SCALE: Level 2

	Enviromental	Social	Governance	Value for money
Enviromental	1	0.735294118	0.555555556	1
Social	1.36	1	0.555555556	1
Governance	1.8	1.8	1	1
Value for money	1	1	1	1
Sum	5.16	4.535294118	3.111111111	4

Normalized			
0.193798	0.162127	0.178571	0.25
0.263566	0.220493	0.178571	0.25
0.348837	0.396887	0.321429	0.25
0.193798	0.220493	0.321429	0.25

PV	Criteria weights
0.193	
0.227	
0.335	
0.246	

Consistenecy

4.047 0.016 0.018

A. SAATY SCALE: Level 3

Enviromental	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.3333333	0.5	0.333333333
DBFMO	1	1	0.5	1	0.5
PR.DBFM	3	2	1	1	0.5
PR.DBFMO	2	1	1	1	0.5
PPP bundle model	3	2	2	2	1
Sum	10	7	4.8333333	5.5	2.833333333

Normalized				
0.1	0.142857	0.068966	0.090909	0.117647
0.1	0.142857	0.103448	0.181818	0.176471
0.3	0.285714	0.206897	0.181818	0.176471
0.2	0.142857	0.206897	0.181818	0.176471
0.3	0.285714	0.413793	0.363636	0.352941

PV	Criteria weights
0.104	
0.141	
0.230	
0.182	
0.343	

Consistenecy

5.111021 0.027755 0.025

Social	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.5	1	0.333333333
DBFMO	1	1	0.5	1	0.333333333
PR.DBFM	2	2	1	1	0.5
PR.DBFMO	1	1	1	1	0.5
PPP bundle model	3	3	2	2	1
Sum	8	8	5	6	2.666666667

Normalized				
0.125	0.125	0.1	0.166667	0.125
0.125	0.125	0.1	0.166667	0.125
0.25	0.25	0.2	0.166667	0.1875
0.125	0.125	0.2	0.166667	0.1875
0.375	0.375	0.4	0.333333	0.375

PV	Criteria weights
0.128	
0.128	
0.211	
0.161	
0.372	

Consistenecy

5.063611 0.015903 0.014

Governance	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.5	0.5	0.5	0.25
DBFMO	2	1	1	1	0.333333333
PR.DBFM	2	1	1	1	0.5
PR.DBFMO	2	1	1	1	0.5
PPP bundle model	4	3	2	2	1
Sum	11	6.5	5.5	5.5	2.583333333

Normalized				
0.090909	0.076923	0.090909	0.090909	0.096774
0.181818	0.153846	0.181818	0.181818	0.129032
0.181818	0.153846	0.181818	0.181818	0.193548
0.181818	0.153846	0.181818	0.181818	0.193548
0.363636	0.461538	0.363636	0.363636	0.387097

PV	Criteria weights
0.089	
0.166	
0.179	
0.179	
0.388	

Consistenecy

5.025333 0.006333 0.006

Value for Money	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.5	0.5	0.5	0.2
DBFMO	2	1	1	0.5	0.333333333
PR.DBFM	2	1	1	0.5	0.333333333
PR.DBFMO	2	2	2	1	0.5
PPP bundle model	5	3	3	2	1
Sum	12	7.5	7.5	4.5	2.366666667

Normalized				
0.083333	0.066667	0.066667	0.111111	0.084507
0.166667	0.133333	0.133333	0.111111	0.140845
0.166667	0.133333	0.133333	0.111111	0.140845
0.166667	0.266667	0.266667	0.222222	0.211268
0.416667	0.4	0.4	0.444444	0.422535

PV	Criteria weights
0.082	
0.137	
0.137	
0.227	
0.417	

Consistenecy

5.051752 0.012938 0.012

B. BALANCED-N SCALE: Level 3

Enviromental	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.523560209	0.704225352	0.523560209
DBFMO	1	1	0.704225352	1	0.704225352
PR.DBFM	1.91	1.42	1	1	0.704225352
PR.DBFMO	1.42	1	1	1	0.704225352
PPP bundle model	1.91	1.42	1.42	1.42	1
Sum	7.24	5.84	4.647785562	5.124225352	3.636236266

Normalized					PV	Criteria weights
0.138122	0.171233	0.112647	0.137431	0.143984	0.141	
0.138122	0.171233	0.151518	0.195151	0.193669	0.170	
0.263812	0.243151	0.215156	0.195151	0.193669	0.222	
0.196133	0.171233	0.215156	0.195151	0.193669	0.194	
0.263812	0.243151	0.305522	0.277115	0.27501	0.273	

		Consistenecy
5.032	0.008	0.007

Social	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	1	0.704225352	1	0.523560209
DBFMO	1	1	0.704225352	1	0.523560209
PR.DBFM	1.42	1.42	1	1	0.704225352
PR.DBFMO	1	1	1	1	0.704225352
PPP bundle model	1.91	1.91	1.42	1.42	1
Sum	6.33	6.33	4.828450704	5.42	3.455571123

Normalized					PV	Criteria weights
0.157978	0.157978	0.145849	0.184502	0.151512	0.160	
0.157978	0.157978	0.145849	0.184502	0.151512	0.160	
0.224329	0.224329	0.207106	0.184502	0.203794	0.209	
0.157978	0.157978	0.207106	0.184502	0.203794	0.182	
0.301738	0.301738	0.29409	0.261993	0.289388	0.290	

		Consistenecy
5.018	0.004	0.004

Governance	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.704225352	0.704225352	0.704225352	0.434782609
DBFMO	1.42	1	1	1	0.523560209
PR.DBFM	1.42	1	1	1	0.704225352
PR.DBFMO	1.42	1	1	1	0.704225352
PPP bundle model	2.3	1.91	1.42	1.42	1
Sum	7.56	5.614225352	5.124225352	5.124225352	3.366793522

Normalized					PV	Criteria weights
0.132275	0.125436	0.137431	0.137431	0.129138	0.132	
0.187831	0.178119	0.195151	0.195151	0.155507	0.182	
0.187831	0.178119	0.195151	0.195151	0.209168	0.193	
0.187831	0.178119	0.195151	0.195151	0.209168	0.193	
0.304233	0.340207	0.277115	0.277115	0.297019	0.299	

		Consistenecy
5.010	0.003	0.002

Value for Money	DBFM	DBFMO	PR.DBFM	PR.DBFMO	PPP bundle model
DBFM	1	0.704225352	0.704225352	0.704225352	0.310559006
DBFMO	1.42	1	1	0.704225352	0.523560209
PR.DBFM	1.42	1	1	0.704225352	0.523560209
PR.DBFMO	1.42	1.42	1.42	1	0.704225352
PPP bundle model	3.22	1.91	1.91	1.42	1
Sum	8.48	6.034225352	6.034225352	4.532676056	3.061904777

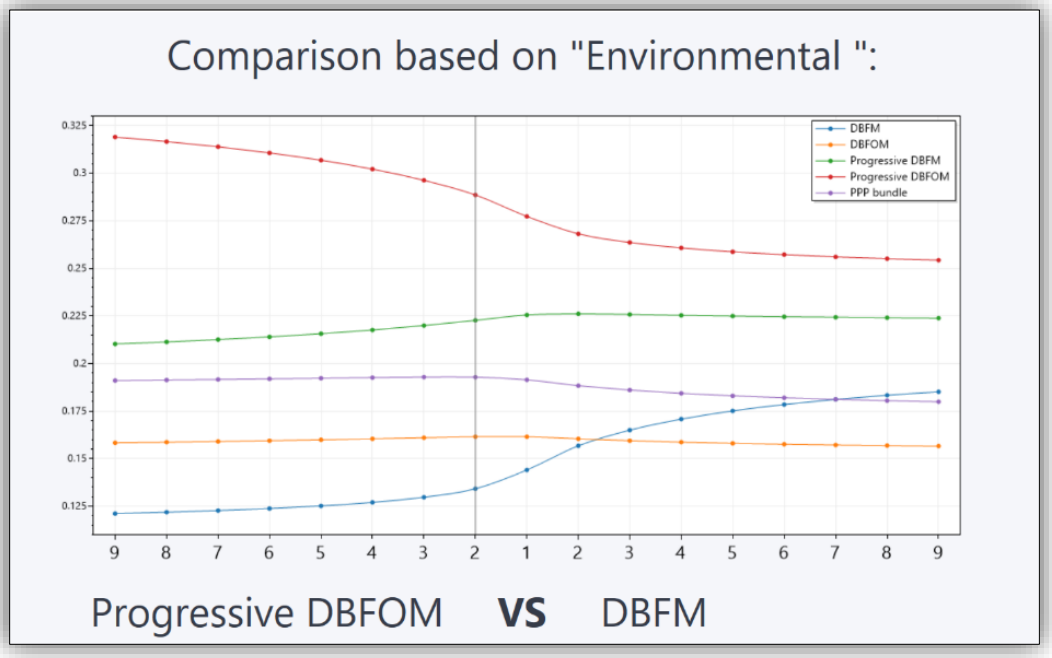
Normalized					PV	Criteria weights
0.117925	0.116705	0.116705	0.155366	0.101427	0.122	
0.167453	0.165721	0.165721	0.155366	0.170992	0.165	
0.167453	0.165721	0.165721	0.155366	0.170992	0.165	
0.167453	0.235324	0.235324	0.22062	0.229996	0.218	
0.379717	0.316528	0.316528	0.313281	0.326594	0.331	

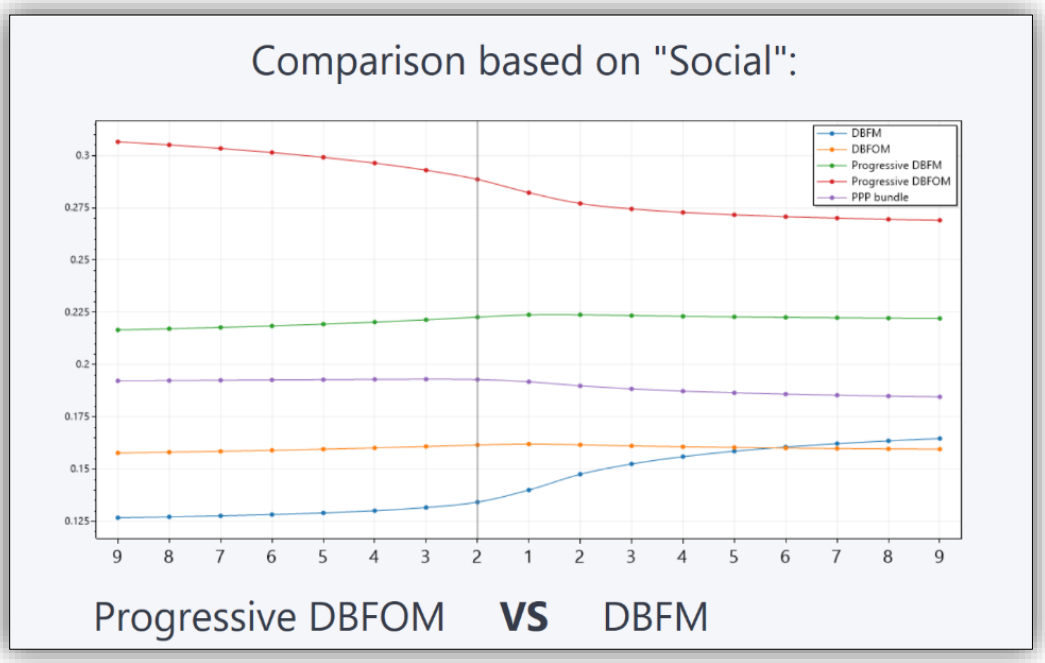
		Consistenecy
5.022	0.006	0.005

Appendix IV

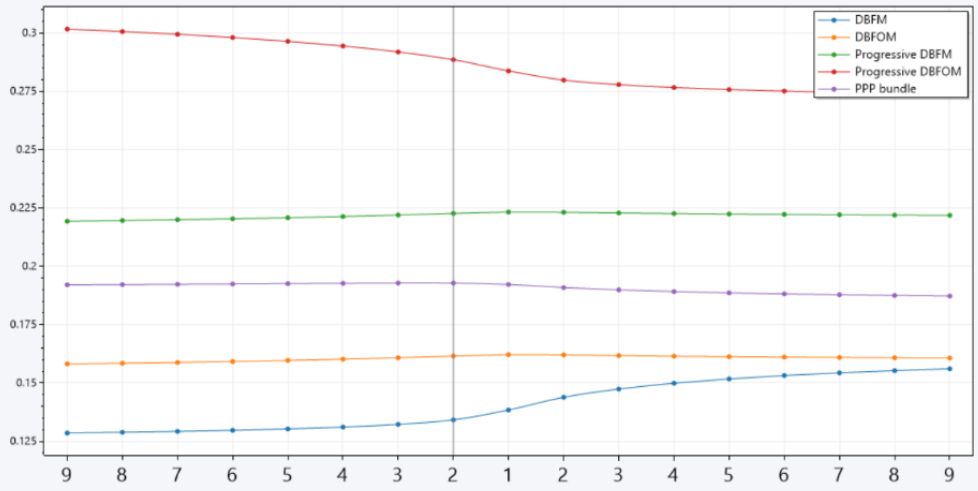
Sensitivity Analysis Graphs

South Niagara Hospital – Sensitivity Analysis



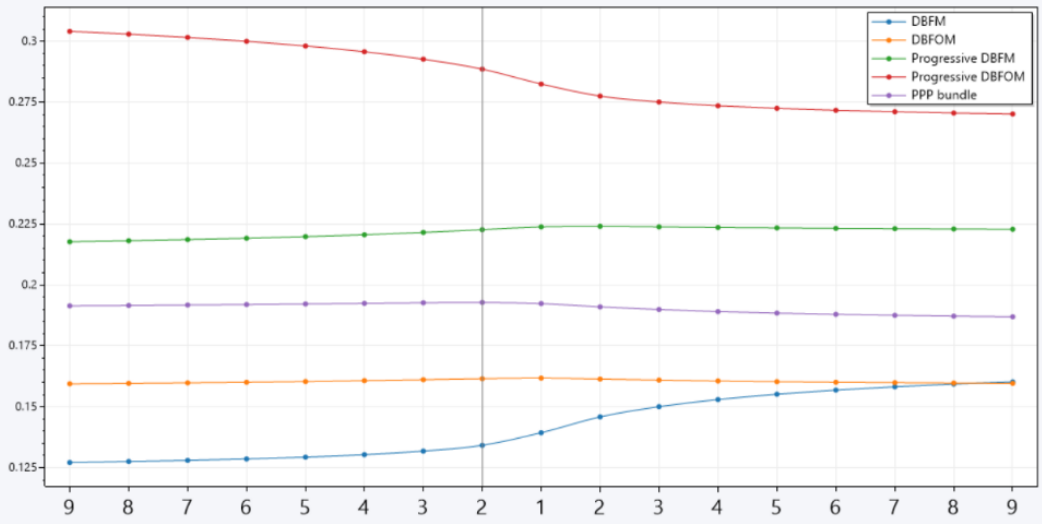


Comparison based on "Governance":

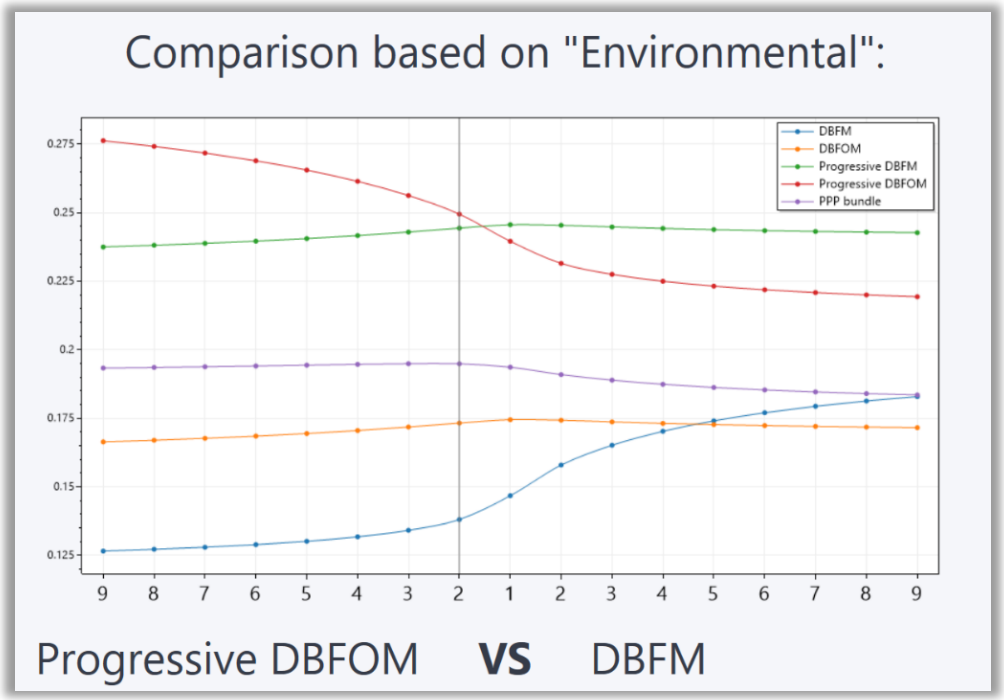


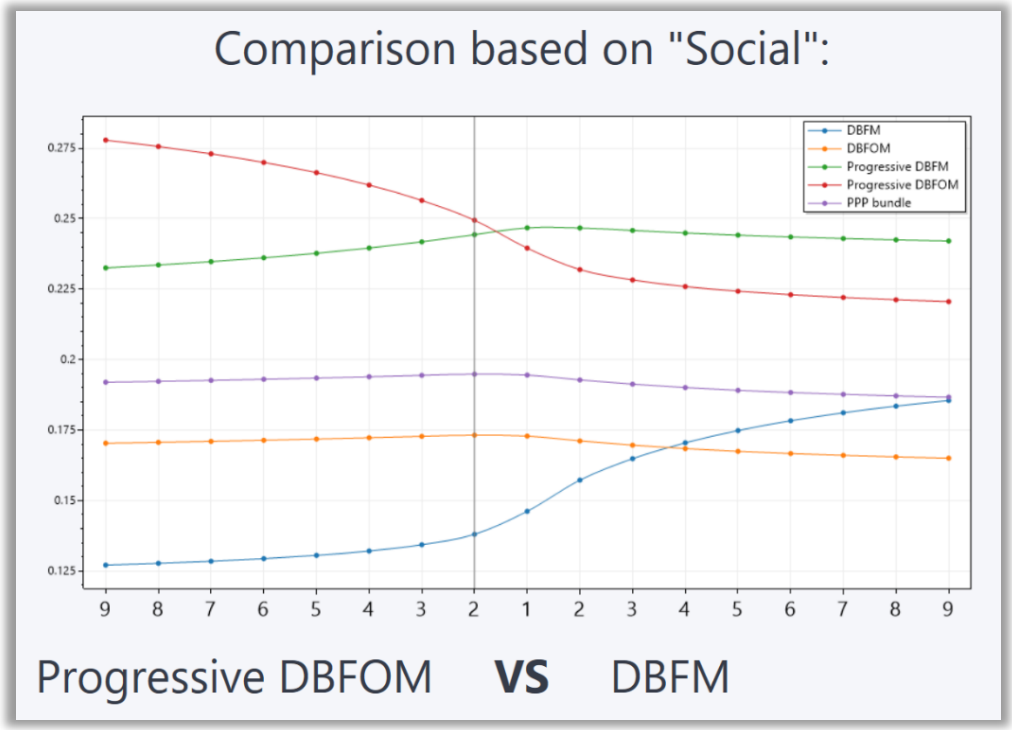
Progressive DBFOM **VS** DBFM

Comparison based on "Value for money ":

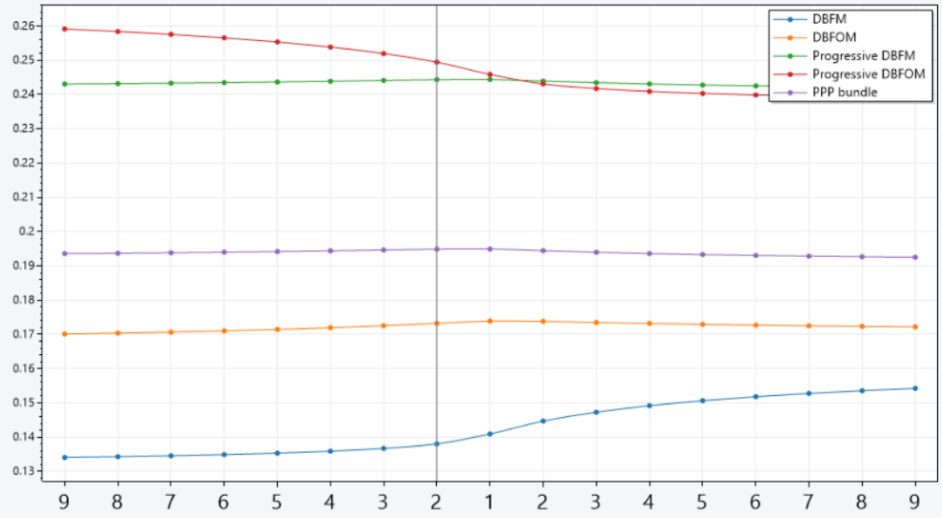


Progressive DBFOM **VS** DBFM


Comparison based on "Environmental":
DBFM
DBFOM
Progressive DBFM
Progressive DBFOM
PPP bundle
0.275
0.25
0.225
0.2
0.175
0.15
0.125
9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9
Progressive DBFOM VS DBFM

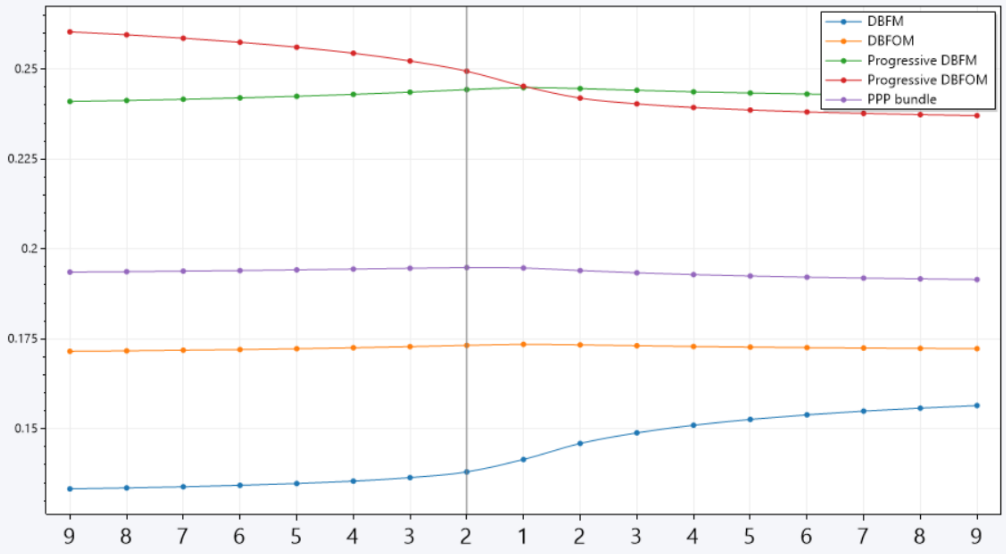

Comparison based on "Social":
DBFM
DBFOM
Progressive DBFM
Progressive DBFOM
PPP bundle
0.275
0.25
0.225
0.2
0.175
0.15
0.125
9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9
Progressive DBFOM VS DBFM

Comparison based on "Governance":

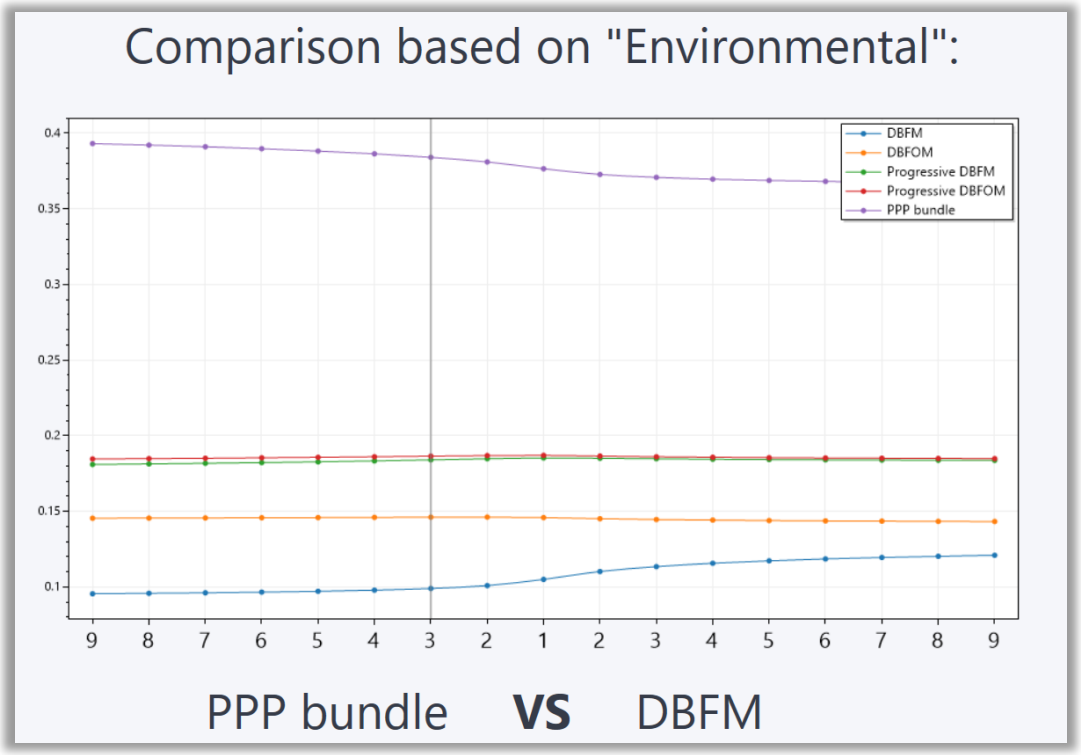


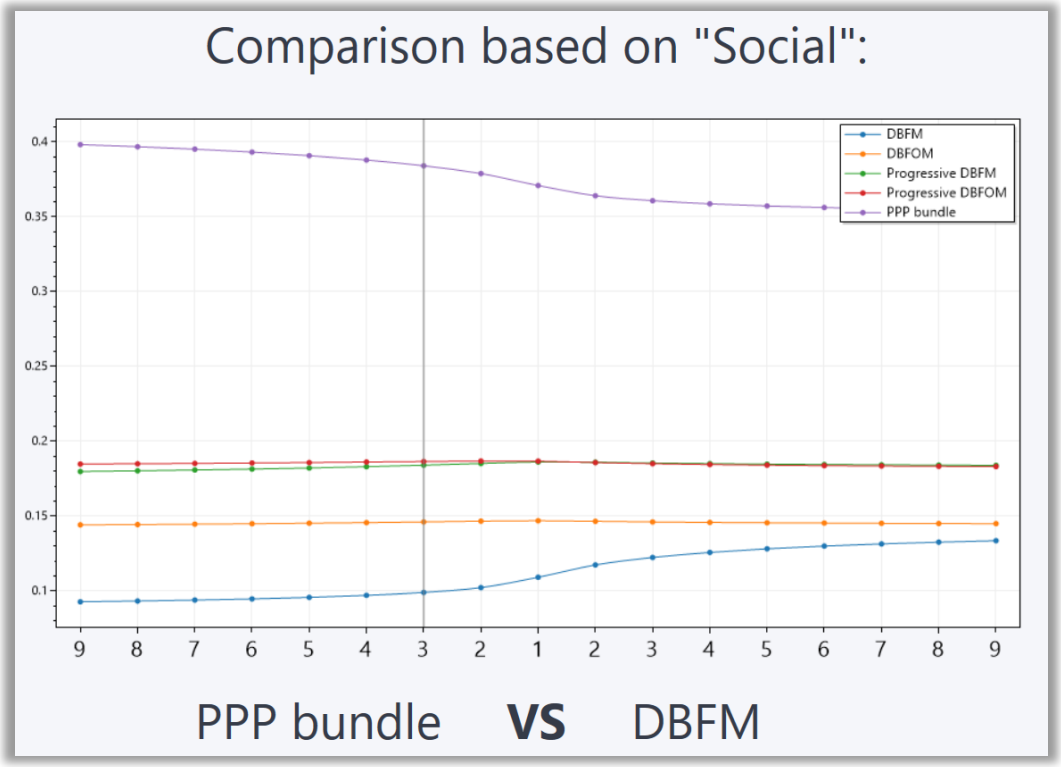
Progressive DBFOM **VS** DBFM

Comparison based on "Value for money ":

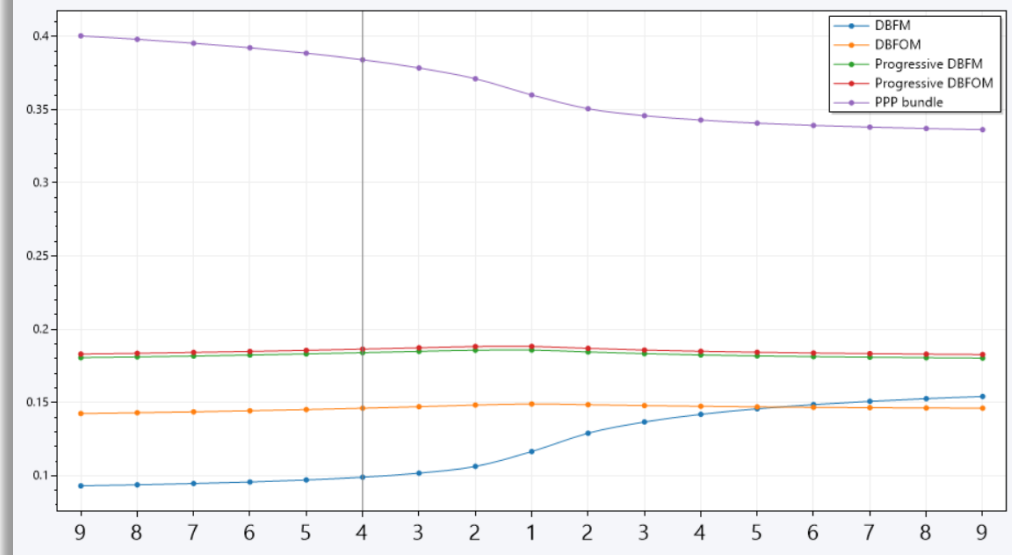


Progressive DBFOM **VS** DBFM


Comparison based on "Environmental":
DBFM
DBFOM
Progressive DBFM
Progressive DBFOM
PPP bundle
0.4
0.35
0.3
0.25
0.2
0.15
0.1
9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9
PPP bundle VS DBFM

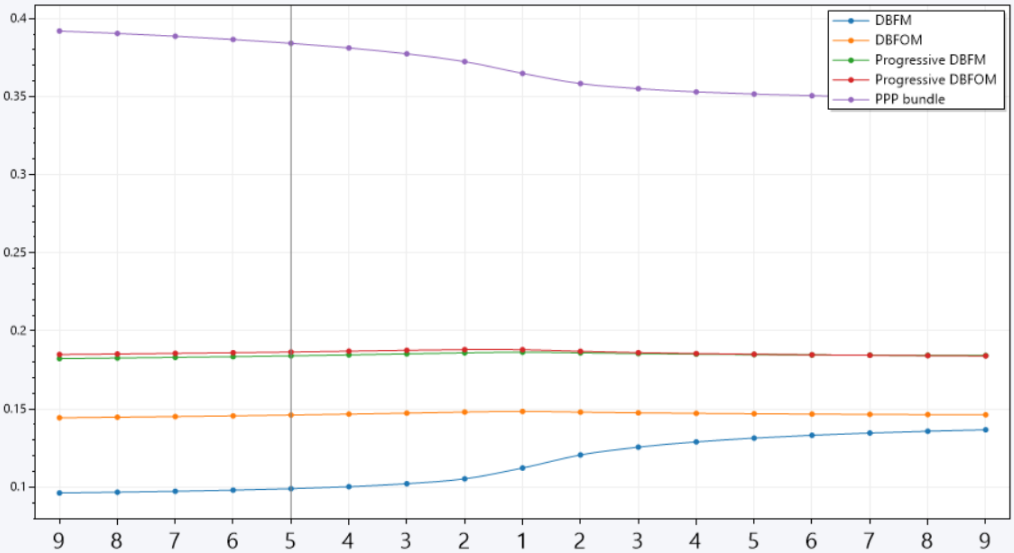

Comparison based on "Social":
DBFM
DBFOM
Progressive DBFM
Progressive DBFOM
PPP bundle
0.4
0.35
0.3
0.25
0.2
0.15
0.1
9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9
PPP bundle VS DBFM

Comparison based on "Governance":



PPP bundle **VS** DBFM

Comparison based on "Value for money ":



PPP bundle **VS** DBFM

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