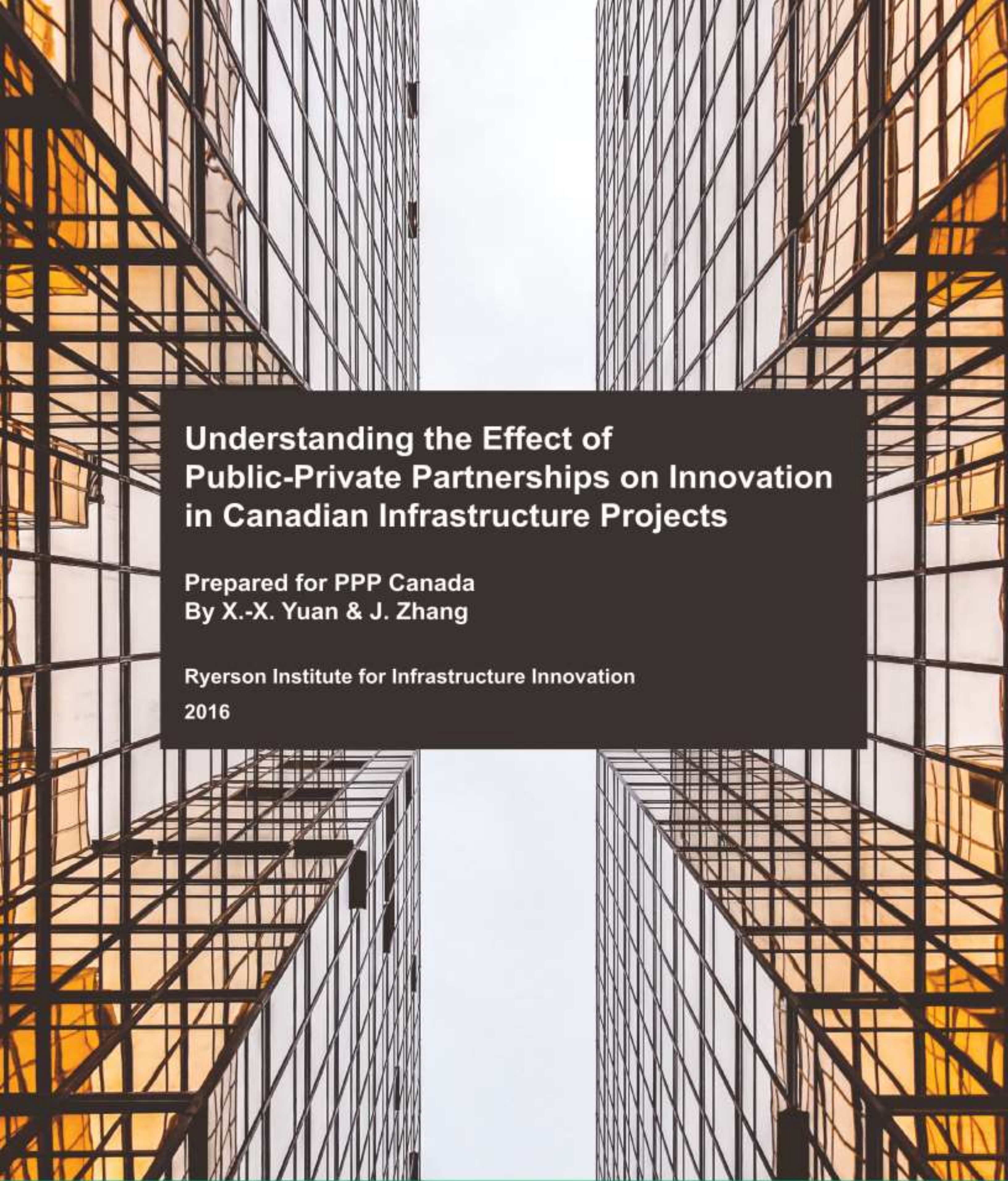

Understanding the Effect of Public-Private Partnerships on Innovation in Canadian Infrastructure Projects

Prepared for PPP Canada

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Disclaimer

The study was conducted by the Ryerson Institute for Infrastructure Innovation under a contract with PPP Canada. This report has been prepared by the authors in good faith on the basis of information gleaned from interviews and literature in the public domain. However, the content does not necessarily reflect the official views or policies of PPP Canada, nor of Ryerson University. The authors are responsible for any biases, mistakes, and misinterpretations the report might have included.

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The study included an interview program to which a number of people made contributions. The interviewees that participated in the study represented a wide range of public-private partnership (PPP or P3) stakeholders including public clients, P3 procurement agencies or departments, private infrastructure investors, engineering consultants, general contractors, and facility managers. The authors are very grateful for the effort and time offered by the interviewees during the study. The authors would also like to thank Beth McAuley for her careful editorial service of the report.

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Acronyms

AFP	Alternative Financing and Procurement, the name used in the province of Ontario for P3
BF	Build-Finance
CCIC	Canadian Construction Innovation Council, an already deactivated not-for-profit association aiming to promote construction innovation in Canada
CIP/MSE	Cast-In-Place/Mechanically Stabilized Earth
CM@Risk	Construction Management at Risk
DB	Design-Build
DBB	Design-Bid-Build, the conventional project delivery model of public infrastructure
DBF	Design-Build-Finance
DBFM	Design-Build-Finance-Maintain
DBFMO	Design-Build-Finance-Maintain-Operate
IO	Infrastructure Ontario
IRR	Internal Rate of Return
LCC	Lifecycle Cost, sometimes also called whole-life cost
LED	light-emitting diode, a lighting technology
LEED	Leadership in Energy and Environmental Design, a green building certification program that recognizes best-in-class building strategies and practices
NPV	Net Present Value
NU Girders	The University of Nebraska's I-girders, known as NU girder
P3	Public-Private Partnership; P3 refers exclusively to the project-based public-private partnerships in this report
PFI	Private Financing Initiative, the British name for PPP
PPP	Public-Private Partnership, same as P3
PSOS	Project-Specific Output Specifications
R&D	Research and Development
REB	Ryerson Ethics Board
RFID	Radio-Frequency Identification
RFP	Request for Proposal

RFQ	Request for Qualification
RIII	Ryerson Institute for Infrastructure Innovation
RTLS	Real Time Locating System
SPV	Special Purpose Vehicle
VfM	Value for Money

Executive Summary

Public-private partnerships (PPP or P3s) have emerged as a mainstream method of delivering public infrastructure in Canada. The use of P3s in Canada has proven to be very successful, particularly after the first stage of experience- and lesson-learning. A majority of the P3s have been delivered on time and on budget. Now that Canadian P3s are moving to their third wave in which the project pipeline has become steadier and more robust, the industry is looking for areas that can be improved in order to further enhance the efficiency gain of P3s. Innovation has been identified as such an area.

Although a number of studies have tried to formalize a theoretical framework to explain and guide construction innovations, disentangling the precise effect of the project delivery model on project performance remains a difficult task. For P3 projects in particular, literature based on practices from Europe seems to provide conflicting evidence: some claimed very positive experiences of innovation in P3s, while others expressed fairly unenthusiastic views, claiming that P3s had little impact on the use of innovation. To bridge this gap, this study collected and analyzed empirical evidence of engineering innovations that have been successfully used in existing P3 projects in Canada.

This study consisted of a comprehensive literature review and an interview program. The research team reviewed archived literature, P3 project documents, and industry reports and presentations related to engineering innovations in P3s that were found in the public domain. The primary research included an interview program involving 19 interviewees from 15 successful P3 projects. Before the interview, a detailed interview protocol was developed in accordance with the research ethics and integrity requirements stipulated by the Ryerson Ethics Board.

Drawing on the literature review and the interviews, we concluded that the P3 delivery system does provide unique innovation opportunities and scope that traditional delivery models (design-bid-build, design-build, and so on) cannot support. Overall, the Canadian P3 industry takes a very positive view on the track record of the use of innovations. Innovations can be further enhanced by the public procurers by introducing more performance-based output specifications and by the private partners' in-depth system integration of design, construction, and asset management.

Other major findings are presented below:

What Is Innovation? Innovation in P3s refers to an alternative design, material, product, process, or method that private proponents use either to maintain their competitive advantage in a bid competition or to meet a certain job challenge during the implementation stage. The alternative solutions may be new ideas; however, they can also be existing ideas that have not yet been routinely used in different projects.

What Innovations Were Used? A great variety of design, engineering, and construction innovations have been adopted in Canadian P3s. Many interviewees could identify at least three key innovations for each project. For a few of the P3 projects in which different private sector stakeholders (e.g., the investor, the design-build team, and facility manager) were interviewed, the same innovations were identified. However, the innovation lists provided by the public and private partners sometimes differed for the same project. This shows that innovation has a varying impact on different stakeholders.

About 60% of innovations identified from the interviews belong to incremental innovations, and the rest are almost evenly distributed among modular, architectural and system innovations. There are four reasons for the prevailing incremental innovations: first, innovation is a means, not the aim, of P3s. Ultimately, the goal of the public procurer is to acquire a quality infrastructure asset and service on time and within budget. Innovation helps to achieve this goal; however, innovation itself is not an evaluation criterion. Second, the bidding competition forces the private sector partners to be creative. However, the schedule constraint of the Request for Proposal (RFP) stage and the risk aversion attitude of both the public and private partners require that proponents exercise great discipline in innovation. For this reason, only proven technology will, in general, be proposed and accepted. Third, many interviewees suggested that the output specifications could be less prescriptive. Prescriptive output specifications offer fairly small technological space for innovation. Fourth, there is still a lack of in-depth collaboration within the project company's design-build-maintenance team to consolidate their construction, operation and maintenance expertise into design.

Visible differences exist in the nature of innovations among different infrastructure sectors. In building P3s (e.g. health care and courts), design innovations occurred more often than construction innovations. Moreover, design innovations focused on areas related to adaption (both technological and demand) and sustainability (architecture footprint, energy performance, water consumption, LEED certification, the use of green materials, and solid waste reduction). Construction related innovations often included construction re-sequencing and modular construction. In contrast, transportation and transit P3s more commonly see innovations by the private sector following financial close in order to address challenges during construction. This is a good indication that P3s have successfully transferred the construction risk to the private sector. Geotechnical risks, traffic management, and durability are the most frequent areas of innovation in transportation P3s.

What Impacts Have Those Innovations Made? The impacts of innovation vary across a wide range. Although the quantification of these impacts is beyond the scope of this study, interview participants from transportation and transit P3 projects reported that an approximate 20 to 30 percent cost benefit has been observed, part of which were attributed to innovation and efficacy in the P3 delivery model.

Who Was Leading Innovations? The study found that although clients played an important role in encouraging innovation through various measures during the RFP stage, the majority of innovations were initiated by the private sector.

Although all P3 agencies and departments in Canada generally encourage innovation, different strategies are used to encourage innovation by the provincial P3 agencies and departments. While British Columbia and Alberta procurers use fairly loose terms to attract proponents for innovative proposals, Infrastructure Ontario often provides explicit criteria for innovation in their RFP documents through the provisions of Required or Preferred Innovation Submissions. For those Preferred Innovation items, the public procurers can be considered the champion of the innovations, even though it is still the responsibility of the proponents to come up with the exact solution for the requested innovations.

When Did Innovations Occur? Innovations were reported to occur over the whole lifecycle. Many private sector interviewees maintained that innovations do not stop until the completion of the project. However, for health care and justice P3s, the majority of the innovations occurred in the RFP stage, whereas key innovations for transportation and transit projects were brought forth and implemented during the construction stage.

Why Were Innovations Proposed? As previously discussed, there are many reasons why innovations were proposed. These motivations can be broadly categorized into two considerations: to get the job, and to get the job done. The major drivers during the RFP stage are (1) cost reduction, (2) specification compliance, and (3) performance enhancements. Here, cost reduction is defined as cost saving in the lifecycle sense, or simply the reduction in the net present value of the total lifecycle cost.

Why Were Innovations Adopted? Almost all interviewees agreed that the proposed innovations were accepted based on cost. The interviews revealed that many more innovative solutions were proposed than were accepted. Reasons for rejection outweigh reasons for acceptance. To be accepted, innovation submissions have to first meet the affordability test as well as enhance performance in some sense. Failing to meet these two criteria results in rejection of the proposal. Moreover, insufficient information about the innovation is also a primary reason for rejection. Meanwhile, the industry is undergoing improvements to enhance the innovation adoption rate. According to the literature review, the clients' suggestion of innovation focus areas helps proponents to better use their resources during the RFP stage and thus encourage innovations, but our interview questions did not explicitly examine this hypothesis. But this is a topic worth further investigation in the future.

How Can Innovations Be Further Encouraged? Interviewees made many suggestions as to how to improve the current innovation procurement strategy. The top three suggestions were: more performance-based output specifications, more effective communication, and more in-depth system integration.

Recommendations

Both the private and public sectors in Canada have demonstrated a strong attitude toward the continuous improvement of procurement models in order to encourage innovation. For future enhancements, the following suggestions were recommended:

1. Public clients are recommended to continue moving away from compliance culture and refocus their resources on addressing strategic issues (such as needs, functionalities, performance, and levels of services) by using systems engineering approaches. This will also help the public clients develop a less prescriptive, truly output-focused project specification. The challenge of developing such a PSOS while satisfying the constraints

from the design codes, standards, and other specifications is recognized. Further research along this line is needed.

2. The private sector partners are recommended to work more closely to fully embrace the lifecycle development opportunities. Lifecycle development needs to address a lot of issues that traditional delivery models have less-often cared about, such as performance deterioration, functional obsolescence, time-dependent reliability, maintainability, and inspectability. Properly addressing those issues would help not only the private and public partners select the optimal lifecycle solutions, but would also help the public client manage the residual value risks of the infrastructure asset.
3. The P3 industry overall is recommended to collaborate more with universities and applied research centres to improve the opportunities for radical innovation. Moreover, it is recommended that both federal and provincial governments enhance the R&D investments in the infrastructure sector. This need is more urgent in the current age of renewed investment interest in infrastructure.
4. In addition to engineering innovation, innovation in financing arrangement is another major benefit that P3s provide beyond the traditional delivery approaches. It is recommended that financing innovation be a subject of future study.

1 Introduction

1.1 Background and Motivation

Public-private partnerships (PPP or P3s) have emerged as a mainstream delivery method for large public infrastructure in Canada. Beginning with early projects in the 1990s, Canadian P3s have now reached their third stage of development – one in which the federal government is poised to play a greater role in coordinating private investment in the country's infrastructure. PPP Canada, a federal Crown corporation, acts as a leading source of expertise on P3 matters by developing and sharing knowledge (PPP Canada, 2015). Canada has been recognized as a new world leader in the use of P3s for public infrastructure delivery.

Public infrastructure can also be delivered through the traditional design-bid-build (DBB) model, in which the architectural and engineering design and construction are undertaken by two different groups under separate contracts. This causes the two often interrelated tasks to be divided by the bidding process. Occasionally, when there is a very tight project schedule, the project may be delivered through design-build (DB), a fast-track delivery method, in which the design and construction professionals team up to provide both services under one contract. To further improve project delivery efficiency, public owners have also tried other delivery systems, such as Construction Management at Risk (CM@Risk) (Alberta Infrastructure, 2001) and long-term performance contracting (Hyman, 2009). By using these traditional models, however, Canada's public infrastructure projects have not always demonstrated a good track record. Several projects suffered from so much schedule and cost overrun that they ended up with "white elephants." The use of P3s in Canada, particularly after the first stage of experience and lesson learning, has proven to be very successful; the majority of the P3s have been delivered on time and on budget (Iacobacci, 2010).

P3s have long been touted as an innovative project delivery method that promotes technological innovation and increases delivery efficiency. The first source of innovation is design innovation, which includes designs used to accomplish project deliverables by using new technology or architectural approaches. This may include aspects such as design features that are focused on enhancing the experience of specific target users, like school children or the elderly. While this does not necessarily help reduce costs, using innovative designs means that a project is more likely to be completed on time and on budget while still meeting its social goals. The second source of innovation is process innovation, which can result in more efficient construction and operation of projects.

With the rapid increase in the number of P3s over the last 20 years and the support of many governments for the use of P3s, researchers have been working to determine the benefits and risks of P3s. Researchers have also examined the critical success factors of P3s in order to help improve the decision-making processes of governments (Hartmann, Reymen, & van Oosterom, 2008; Hoppe & Schmitz, 2013; Ling, Hartmann, Kumaraswamy, & Dulaimi, 2007; Lu, Liu, Wang, & Wu, 2013; Maurrasse, 2013; Roumboutsos & Saussier, 2014; Shapira & Rosenfeld, 2011; Van Gestel, Koppenjan, Schrijver, Van De Ven, & Veeneman, 2008). However, evidence of innovation uptake in P3s from other countries has been diverse. For example, two studies from the UK (Barlow & Köberle-Gaiser, 2009; NAO, 2009) found that although there was substantial opportunity for innovation in P3 projects, private financing was "not any more successful in stimulating innovation than public finance of infrastructure assets" (Winch, 2012, p.119). A report published by the Conference Board of Canada states that innovation can begin incubation in the tendering and planning processes. At this phase, the processes allow for input from private partners and can incorporate flexibility to prepare for unforeseen issues that are common in long-term contracts. However, in the same report, many of the respondents hesitated to fully endorse P3s as inherently innovative, as there are no proper ways to measure how P3s impact innovation despite the fact that innovation is considered a key factor for the success of P3s (The Conference Board of Canada, 2013).

Clearly, the delivery model itself is not, and cannot be, a guarantee of the use of innovations. Understanding the types of innovation used in P3s will greatly improve the ability of all P3 participants to maximize their resources. A few of the issues that need to be studied further in order to understand and measure how P3s impact innovation in Canadian infrastructure projects include:

- Where does innovation come from?
- Which P3 models provide greater innovation potential?
- What factors support innovation?
- How does the public procurer select partners with the best track record or potential for developing innovative solutions?

Another motivation for this study was to determine the efficiency gain derived from the innovation. For each P3 project, public sponsors demonstrate the comparative efficiency of the project delivery system by using a value-for-money (VfM) analysis. However, questions about the VfM methodologies are still lingering (Auditor General of Ontario, 2014; Siemiatycki & Farooqi, 2012). While many of these criticisms have focused on the empirical grounds for the determination of risk premiums in P3s, the efficiency gain achieved with engineering innovations is another area that is lacking a solid empirical basis. Practices in the quantification of the innovation-induced efficiency gain are diverse. For example, in its original VfM method, Infrastructure Ontario (IO) assumed that the capital cost (including construction cost and maintenance/rehabilitation cost, if any) in P3s would be the same as that in traditional delivery. Most recently, IO released the revised VfM method into which an innovation factor was introduced. This factor was estimated to be 10% to 15% (Infrastructure Ontario, 2015). This estimation was obtained by considering the results from interviews conducted by MMM group with leading PPP experts and from IO's internal study on bid spread, which compared the winning bid to the average bid received at the RFP stage. Therefore, IO's revised VfM method actually treats the effects of innovation and competitive bidding collectively, lumping them into a single factor called the innovation factor. It is important to understand the quantitative relationship between the benefit of innovation and the gain from competitive bidding, because there is no empirical evidence showing that the efficiency gain from competitive bidding in P3s should be less than that in the DBB model. Literature on competitive bidding has shown that the bid spread should be a non-decreasing function of the number of bidders. While P3 procurements typically involve three to four qualified bidders, the number of bids in DBB is not necessarily smaller than three. Therefore, IO's updated VfM guide does not fully address the efficiency gain issue. Although the efficiency gain from innovation is beyond the scope of this study, the research is expected to bridge the gap by collecting empirical evidence for engineering innovations that have been successfully used in existing P3 projects in Canada.

1.2 Objectives, Scope, and Significance

Therefore, the objective of the study is to help advance the understanding of P3s by addressing the following questions: What innovative solutions have been used in existing (completed or ongoing) P3 infrastructure projects? What factors have led to the successful implementation of those innovations in P3s but probably not in traditional delivery models? How can we further improve the P3 procurement process to encourage more successful innovations in future P3s?

This study mainly focuses on engineering innovations, which include creative design concepts; innovative design and design methods; the use of new engineering materials, components, and systems; adoption of novel construction technologies, methods, and processes; and the use of project management ideas and tools. Other innovations such as institutional innovations and financial innovations are beyond the scope of this study. Moreover, although there are several different delivery models within public-private partnerships, this study focuses on the most applied model, i.e., the design-build-finance-maintenance (DBFM) model.

The work is expected to establish a better understanding of the factors that affect innovation in P3s by collecting and delivering a directory of projects, the innovations identified in each, the impact of these innovations, and the catalyzing feature that encouraged and supported the innovation. The variables and insights identified by the work will help develop methods for measuring the impact of a P3 on innovation. Ultimately, this work is expected to help form the basis and justification for an in-depth research project where the risks mitigated by innovated designs and process can be incorporated into value-for-money (VfM) frameworks.

1.3 Research Methodology

This study uses personal interviews as the major research method. The interviews focused on identifying innovations in P3 projects and the factors that led to them. This method allows for a clearer understanding of which factors are critical in driving successful innovation by comparing project outcomes.

To complete the work, three tasks were undertaken. First, third-party research, including industry reports, high-level surveys, and academic articles and other publicly available information (e.g., websites, press releases) were reviewed. These research outcomes are summarized and used to develop a robust understanding of the high-level impacts of innovation and of the latest state of research in this area. The key areas that have been investigated in the literature review are identified and listed in **Table 1**. Findings from the literature review are summarized in Section 2.

The second task, or the primary research of the study, was an interview program involving 19 interviewees from different key stakeholders in P3 projects (public procurers, clients, or project companies) who have been deeply involved in the selected projects. At the time this report was prepared, there were over 220 P3 infrastructure projects at various stages of completion across different sectors in Canada. It is impossible to study all of these projects. In selecting the projects to be discussed in the interviews, the following considerations were taken:

1. Only projects that have reached financial close were considered, with preference given to completed P3 projects.
2. Among the many P3 variants, DBF, DBFM, DBFO, and DBFMO were the focus. BF projects were not considered.
3. The project list covered federal, provincial and municipal projects.
4. The project list covered a good range of time, with focus on P3 projects in the third generation, i.e., roughly after 2005.
5. The project covered as many sectors as possible. These included roads/bridges, courthouses, hospitals, transit, and social recreational facilities.
6. The selected projects were known to be innovative.

Table 1: Research topics investigated through the literature review

Research Topics Investigated through the Literature Review Highlighting the Current Status of Innovation Research in P3s
Context and Definitions
Worldwide Trends Canada in the Global context
Comparison of Sectors Sectors: healthcare, transportation, government buildings
Applications and Impacts of P3s on the Procurement Process P3s vs traditional procurement (particularly design-build and construction-management)
Drivers for Innovation Adoption Competitive pressures, strategic investment, globalization, demand for services, new products and services, return on investments, better utilization of physical and financial assets
Impediments to Innovation Security, technical compatibility and integration, complexity and control, strategic and operational management issues, talent and skills, costs and return on investment

After consulting with PPP Canada staff, 19 P3 projects from four provinces (British Columbia, Alberta, Manitoba, and Ontario) in three different sectors (transportation, hospitals, and government buildings) were selected as the basis to identify potential interviewees. The selected projects are listed in **Appendix A**.

The key questions that were addressed through the interview are listed in Table 2. A detailed list of the questions that were used in the interview is replicated in Appendix B. Before the interview, a detailed interview protocol was developed that contained the following:

- The interview questions.
- The projects to be discussed in the interview.
- The criteria and procedure for recruiting interviewees.
- The detailed procedure for the interviews.
- The measures to encourage and maintain interviewees' participation in the study.
- The template consent form to be signed by each interviewee before the interview.
- The necessary measures for maintaining the privacy of the interviewees and the confidentiality of the P3 projects and project-related organizations.
- The necessary measures and procedures to secure the interview data.
- The risk assessment of the study.

Table 2: Research topics investigated through the interviews

Research Topics Investigated through the Interviews Innovations and Deciding Factors
Innovations in the P3 projects—what and when?
Championship of innovation—who? Public agency, private partners, engineers, policy makers (regulators) Supports and constraints of other stakeholders
Outcomes of innovation—how? Efficiency, effectiveness, equity, transparency Externalities and risks
Replicability of the success Lessons learned

The interviews were conducted in-person or through teleconference calls. The in-person interviews were often conducted in the interviewee's office. Before each interview, the research team confirmed the interview location with the interviewee. The interview protocol was reviewed and approved by the Ryerson Ethics Board (REB).

Finally, the data collected from the interview was analyzed with the intention of developing a set of best practices and answering the questions outlined in **Table 3**.

Table 3: Research questions to guide the analysis of collected data

Research Questions
Overall research question: What factors lead to successful innovations in a Canadian P3?
Sub questions: What innovations are allowed in P3s? Where does innovation come from? What factors support innovations? What criteria should be used for defining the success of an innovative solution?

1.4 Report Organization

The main text of the report contains five sections, including this introductory section. Section 2 summarizes the major findings from the literature review. Section 3 summarizes the major interview results followed by a discussion. Conclusions are drawn in Section 4 with recommendations about how the P3 procurement process can be improved in order to promote innovations and further enhance P3 performance in the future. Major references are listed in Section 5. **Appendix A** contains a list of the projects selected for the interview study, and the interview questions can be found in **Appendix B**.

2 Major Findings of the Literature Review

This section summarizes the major findings from the literature review. It attempts to address the following questions:

1. How is innovation defined? What is the general situation with respect to engineering innovation in the construction industry, particularly in the Canadian construction industry?
2. What is the current understanding about engineering innovation? In other words, how are engineering innovations brought forth in the real world?
3. What were other countries' P3 experiences in terms of engineering innovation?
4. What lessons can be learned from the previous research work?

2.1 Context

2.1.1 P3s and Traditional Project Delivery Models

Public-private partnerships represent a long-term performance-based contract between a public-sector party (or public authority) and a private, special project vehicle (or project company) to deliver a piece of public infrastructure. The delivery involves financing and usually at least two of the following tasks: design, construction, operation, and maintenance. Payment to the project company is often made over the course of the contract by either the public authority or the users of the facility. A key feature of Canadian P3s, including Ontario's Alternative Financing and Procurement (AFP), is that the facility remains in public-sector ownership throughout the whole contract period. At the end of a DBFM or DBFOM contract, the operation and maintenance responsibility is handed back to the public authority. It is important to note that the handback is not the handback of the asset ownership.

The procurement procedure for a P3, whether it is a DBF, DBFM, or DBFOM, is very similar across Canada. It involves a development stage and an implementation stage. The two stages separated by a competitive bidding process to select the best consortium, called the winning or preferred proponent. **FIGURE 1** shows the typical procurement procedure of a P3 (Yescombe, 2007). The development stage contains many important tasks and can be further divided into the following sub-stages: business case development; procurement document development; request for qualification (RFQ); request for proposal (RFP); and closing. The business case development addresses strategic investment issues (such as economic and technical feasibility, environmental assessment, funding alternatives, and procurement alternatives). In the procurement document development, the public sponsor, with the aid of advisors, architects, and consults, prepares project-specific output specifications (PSOS), a draft project agreement, and often a reference design as well. The actual procurement transaction consists of two steps (RFQ and RFP). The development stage culminates with a commercial closing, followed by a financial closing. Right after the financial closing, the winning proponent starts the implementation stage with design development and construction. In reality, design and construction are performed in a fast-track mode; that is, construction of leading work packages starts right after the design of that part is complete, even though the whole design may not be complete. In a typical DBFOM contract, the project company is also responsible for the operation and maintenance of the facility for the whole concession period (typically 30 years).

Development Stage					Implementation Stage		
Business case development	Procurement document development	Request for Qualification (RFQ)	Request for proposal (RFP)	Closing	Detailed design	Construction	Operation and maintenance

FIGURE 1: Stages of the P3 procurement process

Design-bid-build has been the conventional procurement method of public infrastructure. In a typical DBB project, the public authority (often through the service of an architect, engineer, or consultant) sets out project specifications and a detailed design of the facility, calls for bids on the basis of the detailed design, and pays progressively for the construction of the facility by a private-sector contractor. Even though a stipulated price contract is often used to control the cost risk, cost and schedule overruns are pervasive due to design changes and other risk factors. Design changes are unavoidable because of the use of separate phases and segregated teams for design and construction. Although construction warranty is often introduced in the construction contract to ensure the quality of work, the warranty period is often short (typically one to three years). Therefore, the public authority has to shoulder the responsibility for the long-term performance of the facility after the warranty period has expired. For regular operation and maintenance, the public authority enters into a contract with another private company, which compounds the management issues.

P3s differ from DBB in many ways. The overall procedure aside, the following features distinguish P3s from the traditional delivery method:

1. *Performance-based specifications*. In a P3 the public authority specifies design requirements in terms of performance and availability criteria, but does not specify how these criteria are to be met. The latter question is left for the private sector to address. This output-focused feature has been thought to provide the project company freedom to choose the means and ways to deliver the asset and services.
2. *Performance-based payment mechanism*. Unlike the traditional DBB, where the contractor would receive progressive payment as construction proceeds, in a P3 the project company will not get paid until substantial completion. Moreover, in a typical DBFM or DBFOM project, a significant amount of the construction cost is held back and paid together with the OM cost through the monthly service payment (the name of the payment varies from one jurisdiction to another) during the whole concession period after construction. This payment mechanism helps transfer the majority of the cost and schedule risk of the asset delivery. Furthermore, the monthly payments are often subject

to adjustments depending upon the availability and quality of the services provided within the payment period. This payment arrangement has been conceived to incentivize the project company to not only deliver the asset on time and on budget, but also to effectively maintain the physical condition of the asset to a specified satisfactory level over the whole concession period. To achieve this, the project company is expected to provide innovative solutions for the whole service they are responsible for.

3. *Lifecycle commitments*. A typical DBFM or DBFOM agreement has a concession period of 20 to 30 years. Within this period, many key components of the infrastructure asset will have to undergo major maintenance, rehabilitation, or replacement. This long contractual period has a twofold importance: on the one hand, the public authority uses it as an extended warranty period; any early failures due to design and construction defects are fixed by the private partner. Meanwhile, this period can also be used by the project company to demonstrate maintainability, further reducing the residual risk for the public client. On the other hand, this long period also incentivizes the project company to plan long-term so that the benefits of any early extra capital investment (such as innovation), if justified, can be harvested in the subsequent years.
4. *Vertical integration*. In a DBB project, different tasks are delivered by different specialized organizations. Under a P3 model where the project company assumes responsibility for design, construction, financing, and operations and maintenance, the various subordinates within the project company (design and construction engineers, construction manager, facility managers) have an opportunity to work together under one roof to provide a vertically integrated solution.

To summarize the discussion from the perspective of innovation, it can be stated that these four features provide a technical space, a financial motivation, a proper time horizon, and an organizational environment, respectively, for the conceiving and implementation of innovative ideas.

2.1.2 Success Factors of P3s

Previous literature reviews in this area have identified four aspects that are consistent with and indicate conditions for successful P3 projects in various regions. These include (1) the competence of the government, (2) the selection of an appropriate concessionaire, (3) an appropriate risk allocation between the public and private sectors, and (4) a sound financial package (Cheung, Chan, & Kajewski, 2012). Going deeper into this issue, the United Kingdom conducted a review of their P3s and found five conditions that lead P3s to fail. These conditions include (1) transaction costs that are disproportionate to the value of the project, (2) fast-paced technological changes that make it difficult to establish long-term service requirements, (3) the nature of the services being delivered not allowing the public sector to clearly define its needs over the long term, (4) insufficient attention being paid to projecting future demand, and (5) projects moving forward, not on the basis of a genuine comparison of the options but because of artificial incentives established by public policy. These findings are in line with a report from the

Fraser Institute (Lammam, MacIntyre, & Berechman, 2013), in which it outlines the following as criteria for a successful transportation P3:

- Several qualified private-sector firms competing for the contract.
- Potential for innovation, particularly in design and service delivery.
- A dedicated revenue stream attached to the service provided.
- A feedback loop from pricing to service.
- Synergies from bundling and assigning multiple tasks to one entity.
- Potential for risk transfer to the private sector.
- Expertise and skills required for the project being less available in the public sector.
- Clearly definable and measurable output specifications.
- A project large enough to spread out the initial cost of structuring a contract.
- Flexible lead time to allow for proper contract negotiation.

2.1.3 Canadian P3 Market

Over the past decade, P3s have become the prevailing delivery approach for large-scale infrastructure projects worldwide. Under the multilayered pressures due to fiscal constraints, aging infrastructure, and economic growth needs, the Canadian governments at the federal, provincial, and municipal levels are increasingly adopting P3s to leverage their investments and provide a high quality life to citizens through modern public infrastructure. Meanwhile, both highly competitive, strong private-players and growing public institutional capacity has impelled the prosperity of the Canadian P3 market, making Canada a world leader in the use of P3s.

The white paper from the Canadian Council for Public-Private Partnerships (CCPPP, 2015) characterizes the Canadian P3 market as providing a "a stable pipeline, efficient procurement, vigorous competition in supply and a supportive political environment." Based on the database from the CCPPP at the time of preparing this report, there have been over 220 infrastructure projects across different sectors delivered by the P3 approach, representing over $70 billion of capital investment. A detailed breakdown of the P3 projects is summarized in **Table 4.**

Table 4: Number and capital values of P3 projects in Canada (all jurisdictions)

Sector	Number	Capital Value (C$ million)
Transportation	49	31,405
Hospital & Healthcare	83	22,418
Justice & Corrections	19	5,458
Energy	6	4,458
Education	11	1,746
Recreation & Culture	17	1,380
Environmental	24	1,229

Real Estate	4	944
Defense	1	867
Government Services	4	482
IT Infrastructure	2	1
Total	**220**	**70,388**

A survey conducted by InterVISTAS Consulting Inc. concluded that Canadian infrastructure P3 projects have had a positive impact on the national economy over the past decade. Based on the P3 projects from 2003 to 2012 and using economic impact software, the research team found that "the economic impacts of the Canadian infrastructure P3 projects support direct employment of 290,680 FTE jobs, earning $19 billion in direct income/wages and benefits, and contributing $25.1 billion in direct GDP to Canada." The survey concluded that infrastructure P3s are an important generator of taxation revenues for the federal and provincial governments (InterVISTAS, 2013).

2.2 Concepts of Construction Innovation

2.2.1 Definition

Before any meaningful discussion about innovation, it is important to agree upon what the notion of innovation really means. There have been many definitions of innovation in literature (for example, Construction Industry Council, 2000; Freeman & Soete, 1997; Russell, Tawiah, & De Zoysa, 2006; Tatum, 1986). Everybody would agree that innovation has to do with something that is novel. However, novelty itself is a slippery concept, as the degree of novelty and the extent of impact of the innovation are subject to different interpretations and expectations. For example, in architectural design, some architects differentiate innovative design from the best practice. For them, innovation must involve a radical change in design concept or in the use of materials and systems. But some other architects would argue that the first-time adoption of a best practice (e.g., LEED, a green building certification program that recognizes best-in-class building strategies and practices) should be a qualified innovation. Similarly, in construction engineering, some people argue that standardization of construction methods and component modularization is innovation, whereas others consider these only routine process improvements.

Innovation is not invention, and neither is invention necessarily an innovation. Among many definitions in literature, a generally acceptable definition considers innovation as the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the organization developing the change (Slaughter, 1998). The phrases "*actual use*" and "*novel to the institution*" are the two key phrases that distinguish innovation from invention. Therefore, any creative idea has to be implementable and implemented before it can be considered an innovation. On the other hand, the new idea does not have to be brand new. As long as the organization that develops the innovation has not *comfortably* applied the change before, it is a qualified innovation. Here the word "comfortably" implies two things: first, it does not have to be the first time application of the idea; rather, it has to be the first batch of applications; and second, the application of innovation involves a learning process. Since innovation always involves risk, it requires several similar applications of the same innovative ideas before one develops a comfortable balance between innovation and the risk involved. Only until then, the solution turns to a routine best practice. Without oversimplifying, it can be stated that invention is relative to the state of the art, whereas innovation represents the frontier of the state of practice. Or simply put, innovation is the best of the best practices.

In the context of a P3, Russell et al. (2006) present an outcome-focused definition of innovation. Specifically, they define innovation as "the use of advanced technologies, methodologies, and creative concepts that result in a positive incremental change in basic project performance metrics" (p.1523). Here the project performance metrics include construction schedule, capital and life cycle costs, quality, scope, capacity (or level of services), revenue, safety, and environmental impact. These metrics may be further aggregated into a composite performance measure, for example, the net present value (NPV) and internal rate of return (IRR). Sometimes innovative solutions are introduced to mitigate certain project risks. Thus project risk in terms of variation of each of the above-mentioned metrics is also an important performance metric. Note, however, the adoption of innovative solutions may increase or decrease project risks, because risk-mitigating innovations often come with their own risks. Therefore, in the composite indicator level, an innovation is said to occur as long as there is an increase in the average NPV or IRR, or a decrease in the variation (in terms of, e.g., the standard deviation) of the NPV or IRR.

2.2.2 Classifications

There are several ways of classifying innovations. For example, based on the areas that innovations affect, innovations are classified into product innovations, process innovations, organizational-contractual innovations, and financial-revenue innovations (Russell et al., 2006). Based on the outcome, innovations are also divided into cost-saving innovations and product-enhancing innovations (Construction Industry Council, 2000). The former refers to an innovative solution that reduces the cost, particularly the lifecycle cost (LCC), of the solution. The latter implies an improved product or service for which the customer is prepared to pay more because the cost efficiency is justified.

Incorporating different types of innovation into an infrastructure project requires different types of activities and resources. In general, as the degree of change associated with an innovation increases, the activities and resources required increase as well. Based on this observation, Slaughter (1998) provides another classification system based on their degree of change from the current practice and their links to other components and systems. The classification contains the following five types in increasing order of the degree of change:

1. Incremental innovations
2. Modular innovations
3. Architectural innovations
4. System innovations
5. Radical innovations

An incremental innovation represents a small change that is usually derived from current knowledge and experience. It is believed that this type of innovation can occur at any time in the project. Because of its negligible interaction with other components and systems, the impacts of an incremental innovation are often limited within a fairly narrow range. Only task-level coordination and supervision are required in implementing this type of innovation. Cross-organization involvement usually is not required. An example of incremental innovation is a full-body safety harness for fall prevention.

A modular innovation implies a significant change in a core concept of a component, but leaves the links to other components and systems untouched. It can happen in both design and construction stages. In other words, the innovation can be a product innovation or a process innovation. Either way, the modular innovation requires an early commitment of activities and resources in the corresponding stage. A modular innovation in design is highly affected by the output specifications. A highly technically prescribed specification will limit the possibility of modular innovations. In contrast, a performance- or function-based output specification provides the design team with more room to test innovative ideas, which may lead to a core change in the design concept. Modular innovations can also occur during the construction stage. In this case, it is important for a construction company to implement effective knowledge management. A typical modular innovation is the modular construction technology for restrooms in a hospital.

Unlike modular innovations, an architectural innovation involves a minor or negligible change within a component, but a major change in the links to other components and systems. Because of this, architectural innovations often require fewer special technical resources, but they do require a great deal of coordination and supervision among affected parties, which in turn implies a wide range of timing for commitment, from design through construction to operations and maintenance. It should be noted that architectural innovation does not mean innovations in building design introduced by an architect, although sometimes those innovations may be called an architectural innovation in this particular sense.

System innovations have the attributes of both modular and architectural innovations. They often result from integration of multiple independent innovations that must work together to perform new functions or achieve a new level of performance as a whole. Similar to architectural innovation, system innovations require an early commitment at the conceptual design stage, and explicit and implicit coordination among the whole project team. The manager needs to have both technical and system competence to assess the complementary changes in the other relevant systems or subsystems. An example of system innovation is the development of HVAC system that would allow 100% fresh air in hospital, as it requires not only the complete re-design of the traditional HVAC system, but also requires full life-cycle evaluation and optimization of the system in different aspects including heating, cooling, energy consumption, and air quality.

A radical innovation, by its name, means a revolutionary change in doing things or in providing services. Implementation of a radical innovative solution often entails great financial and project risks, and thus demand commitments from the top management levels of all stakeholders. Radical innovations are rarely observed in the construction industry. According to Slaughter, the introduction of structural steel into construction over a hundred years ago could be considered as a radical innovation, as a whole new industry of steel manufacturing and fabrication emerged, and indeed, many of the design concepts were also changed.

If radical innovation rarely occurs in practical P3 projects in which risk aversion controls risk management, can we expect modular, architecture, and system innovations? If yes, can we do more? If not, why not and what can we do to make them happen? These are the types of questions that we needed to address in the subsequent interview study.

2.3 Performance of Construction Industry in Innovation

Before discussing innovations in P3s, it would be beneficial to take a step back to review the innovation experience in megaprojects, in general, and the experience in Canadian industry, in particular. This will set up a societal background of construction innovations at a macro level.

2.3.1 Lessons Learned from Mega-Projects in General

Bent Flyvbjerg is one of the leading researchers on mega-project management. Beginning in the 1990s, he and his team at Aalborg University, Denmark, started a systematic study of issues involved in planning and management of mega-projects – it later came to be known as the Aalborg study. While the early findings are summarized in two monographs (Flyvbjerg, Bruzelius, & Rothengatter, 2003; Priemus, Flyvbjerg, & van Wee, 2008), the first is of greater relevance to this study. Flyvbjerg et al. (2003) started with a series of empirical studies on the performance of mega-projects, including cost estimation, travel demand forecast, environmental impact assessment, and prediction of regional and economic growth effects.

These empirical studies led the authors to believe that there had been a *mega-project paradox* – more and larger mega-projects were promoted and built despite the poor performance record of many earlier projects. In other words, people learned very little from those expensive project lessons. The authors identified the main causes of the mega-project paradox to be *inadequate deliberation* about risk (or risk negligence) and *lack of accountability* in the project decision-making process. Power play often characterizes mega-project development. To resolve the paradox, Flyvbjerg et al. (2003) replaced the conventional decision-theoretic approach to mega-project development with a more current institutional approach centred on the practices and rules that comprise risk and accountability. In particular, they advocated public involvement in carefully designed deliberative processes from the beginning and throughout a large-scale project to ensure that better risk-informed decisions were derived from the democratic processes. Moreover, to break up the power play and promote accountability, particularly accountability toward risk, they suggested using the following four basic instruments of accountability:

1. Transparency
2. Performance specifications
3. Explicit formulation of regulatory regime
4. Substantial involvement of risk capital

In the end, the authors proposed two alternative models for accountable mega-project decision making: the concession approach and the state-owned enterprise (SOE) approach. Both approaches would place greater emphasis on public involvement and stakeholder participation at the very early stage of the project.

In addition to the alternatives proposed by Flyvbjerg et al. (2003), Rothengatter (2008) examined the aspects of new institutional arrangements and innovative assessment tools to improve the performance of the planning process for mega-projects. As well, after an international scan of innovation practices in 15 OECD countries, Manseau and Seaden (2001) made two interesting points:

- "Governments remain major buyers of construction services and more open acquisition policies that promote long-term value and performance rather than the initial cost, appear to stimulate innovation."
- "Greater emphasis on performance against defined objectives is likely to enhance innovation. Such objectives, that govern safety of occupants or users of buildings and infrastructure as well as compatibility with community values and longer-term sustainability, need to be introduced in regulatory measures" (p.386).

2.3.2 Canadian Construction Industry

It was hoped that an informed understanding of the overall innovativeness in the current Canadian construction industry would help set the tone for the discussion of innovation in the P3 market. Unfortunately, there has been very limited work done in this area, with two notable exceptions: a study conducted in the late 1990s and another in the mid-2000s.

The National Research Council of Canada (the Institute for Research in Construction) and Statistics Canada (the Science, Innovation and Electronic Information Division) jointly initiated a three-year collaborative research project in 1996 to conduct a survey of the advanced technologies and practices in the construction sector (Seaden, Guolla, Doutriaux, & Nash, 2001). It was the first survey of this kind in Canadian history. The broad objective of the project was to measure, understand, and assess innovation, advanced technologies, and practices of the Canadian construction sector with a view to developing new policies and programs. According to the study, the construction industry in Canada has lagged behind other sectors of industry by various indirect measures. In particular, Canadian growth in labour productivity in construction has lagged behind the manufacturing and business sectors and, in fact, decreased during the 1980s and 1990s. A lack of innovation was tapped as one reason for the low performance in construction. As partial evidence, construction R&D investment was found to be much less than in other industries. While the overall cross-industry averaged R&D investment took about 1% of the GDP during the period 1992–98, in the same period overall, expenditure on construction R&D activities in Canada was estimated at 0.01% of the GDP in 1998. This investment was much lower than other OECD countries (e.g., both the USA and UK spent about 0.5% of the GDP on construction R&D activities) (Seaden et al., 2001).

A major limitation of the study was the assumption made that the use of advanced practices implied innovation. Nevertheless, the study did make several interesting findings (Seaden et al., 2001). For example, it was found that technology and business innovativeness within construction firms increase with size: larger firms tend to use three times as many advanced technologies or business practices as smaller firms. Rapid technological change and materials obsolescence appeared to be a clear impetus for engaging in innovation strategies. The study also confirmed the heterogeneity of the Canadian construction industry in innovation: although the most innovative contractors from civil engineering, residential building and non-residential building industries all displayed strong interests in technological innovations, the civil engineering contractors tended to display human resource strategic thinking while the residential building contractors displayed marketing strategic thinking. Moreover, based on the limited financial data used in the study, it was observed that the more profitable residential building contractors and civil engineering firms tended to be less innovative than the less profitable firms in the same industry group. The opposite was found to be true for non-residential contractors where innovativeness seemed to be more cost-effectiveness. Another finding was that, except in the residential building industry, innovation was perceived by the respondents as an added risk rather than as a competitive advantage.

In another publication that is based on the same 1996 survey, Manseau and Bellamy (2001) analyzed various research and innovation programs in Canada. In the end, they recommended that an integrative approach that takes into consideration all key players – from building product manufacturers and designers to builders and end-users – will be crucial to enhance innovation in construction. The current P3 model is clearly aligned with this integrative approach.

The second study reviewed here was commissioned in 2005 by the Canadian Construction Innovation Council (CCIC), which gauged the overall performance of the Canadian construction industry (Rankin, Fayek, Meade, Haas, & Manseau, 2008). The study reviewed a plethora of performance metrics, including cost, time, scope, quality, safety, sustainability, and innovation. In the study, the innovation was further broken down to include procurement innovation, management innovation, and technological innovation. The questions asked to assess the technological innovation were along the lines of: Did you use a product, equipment, or technology in the construction project that was new to your organization? This definition of innovation is similar to the one that is used in this P3 innovation study being discussed in this report. The research group of the CCIC selected 37 construction projects from both public and private sectors to test the validity of the metrics. Unfortunately, the information for innovation was not readily available during their preliminary interview study for many of the projects. However, the limited information did indicate that innovations occurred more in technology than in management and procurement. Moreover, the technological innovations were generally incremental rather than drastic in nature.

2.3.3 International Experiences of Engineering Innovation in P3 Projects

In this section, the international experiences of engineering innovation in P3s are reviewed. Although infrastructure P3s have been used in many countries, there have been few empirical studies on engineering innovations in P3s, except for the UK. The review thus focuses on the experience of the British version of P3s, i.e., the private finance initiative (PFI). A few other relevant studies outside the UK are also reviewed.

Tested as early as in 1984 and with policy formalized in 1992, the British PFI has a long implementation record. To respond to the fast growth of PFI at that time, the Construction Industry Council commissioned a study in the late 1990s to understand the role of cost saving and innovation in PFIs (Construction Industry Council, 2000). In this study, a wide survey among PFI project managers was carried out and three case studies were analyzed. The study focused on cost-saving innovations (CSI), where cost saving is defined as cost saving in the lifecycle sense. Therefore, the CSI includes quality improvement aimed to increase durability, reduce operation costs, and reduce losses from non-availability of service. Many interesting findings were obtained from the survey. Examples include:

- The median total cost savings in the range of 5% to 10%, with transportation and custodial projects having the highest cost saving in the range of 10% to 20%.
- While the scope for CSI is found in diverse areas, innovations in road and utilities projects were mainly technological, whereas innovations in building projects were more business oriented and much less frequently technologically based. The most typical technological innovations involved standardization of design, prefabrication, and equipment-for-labour substitution in operation.
- Among all the innovations mentioned, the majority of them were reported to be incremental.
- Quite interestingly, although respondents of the survey firmly opined that the form of output specifications (performance, functional, or technical) was an important factor that influenced the innovation opportunities, the data collected from the survey was not able to clearly support or refute the proposition.
- Competition plays a crucial role in stimulating innovation in the context of competitive bidding where innovation-seeking expenditure of time and effort had to be written off as a loss if the bid turned out to be unsuccessful. It was speculated that innovation should occur more in response to pressure to increase the probability of winning the bid than in response to the size of the extra profit expected from the innovations should the bid be successful.
- Key innovations typically occur in early development and competition stages of the project.
- When asked for contractual reasons (instead of technological reasons) why the CSIs in the PFI project would not have been implemented in a non-PFI environment, respondents attributed the inhibitors to weak incentives to innovate or organizational barriers to doing things differently, rather than “technical codes/norms” or “contractual arrangement with third parties.”
- Respondents from public clients, SPVs, and SPVs’ suppliers expressed different views toward the characterization of the project specifications (being function-, performance-, or technology-based). The public clients were often optimistic of the performance or function-performance nature of the specifications, whereas the SPV and SPVs’ suppliers felt that the specifications were still too technical and prescriptive.

The innovation experience in the UK PFI study became even more lackluster. A survey of construction managers and project authorities working on the first generation of P3 projects found that "[t]here has been innovation but it has often been limited" (National Audit Office, 2001, p.26).

Another study done by the Major Project Association in the UK, based on interviews with leading actors in the P3 projects, suggested that financial pressures, open bidding, and resistance by government authorities had contributed to hindering the use of innovative solutions in P3s. Both private infrastructure investors and public sector clients wanted "tried, tested and therefore low risk, solutions" (Davies & Salter, 2006, p.79). Drawing on the 30 years of PFI, Winch (2012) provided a fairly depressing assessment: "These data, however inadequate, suggest private finance is not any more successful in stimulating innovation than public finance of infrastructure assets" (p.119).

In a paper prepared for the Lords Economic Affairs Committee in October 2009, the UK's National Audit Office (NAO, 2009) provided an analysis (pp. 27–28) for the unexpected innovation performance of PFI. First, the time pressure during the procurement stage left little time for both the public and private partners to work on design issues. The urge to finalize the commercial and financial closings further squeezed the time for innovation. After all, innovation is only but one item among the busy agenda of the whole procurement process. Second, the PFI procurement process was found to isolate architects from end users. End users were found to engage simultaneously with multiple bidders. As such, the end users rarely had sufficient time to provide the best inputs to the architects. Third, the PFI's emphasis on risk allocation sometimes led to the private proponent's provision of tried and tested solutions. The study found that public authorities that emphasize their intention of achieving innovation in design are more likely to achieve it. Fourth, sometimes the negotiation process at the end of bidding had to be used carefully. If the discussion was on affordability and/or scoping, innovative items were often the first batch to be abandoned.

That being said, it is important to recognize the differences between the British and Canadian P3 models. Canadian P3s may not necessarily suffer from the above-mentioned challenges. For example, Canadian P3s have a better mechanism to ensure affordability and avoid scope creep. End-user communication and engagement tend to be fairly fluid and effective. However, the time constraint in procurement and risk allocation strategies are equally present in Canadian P3 models.

Priemus (2009) described a tendering catastrophe in the project responsible for the Dutch High Speed Railway Link between Amsterdam and the Belgian-Dutch border in the period 1998–99. Although the whole project involved a DBFM contract for the superstructure work, the case study focused on the delivery of the substructure work, which was arranged by five segmented design-build (the original paper called it design & construct) contracts. Using this case study, Priemus tried to determine whether DB contracts stimulate innovation. The failures of the project gave an obvious answer, that is, DB contracts do not necessarily stimulate innovation. In fact, if the project environment is not DB-friendly or if a strong contracting authority is not in charge, DB may result in a delivery disaster. Several general lessons were drawn from the case study. Among those, the following ones are particularly interesting:

- Integrating design and construction, DB requires that the project be delivered as a whole. Dividing a project into several smaller pieces (albeit each piece may still be fairly large) and inviting a DB contract for each piece can create interface problems and communication breakdowns, which lead to tendering and delivery disasters.
- Output-based functional programming, rather than input-based technical specification, cannot be overemphasized.
- DB requires a real competitive procurement market. Collusion, price-fixing, and bid cartels are the enemies of innovation in DB.
- The potential of innovation in DB depends on the technical complexity of the project. The more technically complex the project, the more probable the DB will stimulate innovation.
- DB requires that both the client and construction consortia have a strong innovation culture. This means that when preparing the functional requirements and performance specifications, the client must strike a subtle balance among the factors of cost, quality, scope, schedule, and safety. Meanwhile, the construction consortia, including the design team, must also have a strong investment track record in research and development (R&D) for innovative ideas, technologies, processes, and management.

Rangel and Galende (2010) conducted a quantitative empirical study to explore the determinant factors that can influence the innovation process in P3s by using a sample of 68 highway P3 projects in Spain between 1996 and 2005. Four project characteristics were considered as explanatory variables (or factors) in the experimental design and subsequent factor and multiple regression analyses: (1) the type of risk assumed by the private sector; (2) the transfer of design responsibility; (3) the provision of penalties if the infrastructure does not meet the quality factors specified in the contract; and (4) the number of competing bidders. Innovation, which is the dependent variable of the statistical study, was measured by three alternative quantities: R&D activities (in terms of R&D expenditures and the number of working hours in R&D); other innovative activities (in terms of other innovative activities expenditures and the number of working hours in those activities); and the number of innovations (both product and process innovations are considered). The results showed significant statistical association between the R&D activities (a surrogate that the authors used to measure innovation) and three of the four project characteristics, except the transfer of design responsibility. No significant association was observed between the other innovative activities and the project characteristics. It was also found that only the variable of provision of penalty clauses in contracts could explain a small portion of the variation in the number of innovations, and the other characteristic variables were found not to have a significant relationship with the number of innovations. In the end, the authors suggested that "designing a PPP project with these characteristics will result in companies putting major efforts into R&D activities" (p.53).

Overall, although the Rangel and Galende (2010) study quite possibly represents the first empirical study that tried to quantify the relationship between innovation and various characteristic variables of PPP contracts, it is limited in several aspects. First, the financial investment and human resources spent in R&D and other innovative activities serve at best as an indirect proxy of innovation. In many situations, the relationship between R&D activities and the materialization of innovation is too remote for one to use the former to gauge the latter. According to Slaughter (1998), there are many other types of innovations in construction projects that do not require significant R&D investment. Second, the study involves weak factor or principal component analyses for the independent variables in order to obtain simple, aggregated variables for the “type of risks” and “penalties.” These analyses could have distorted the multiple regression analysis and added difficulty in interpreting the results. Third, the study is limited to PPP projects in Spain, and the results cannot blindly be extrapolated to the other jurisdiction, as innovation has been known to be strongly influenced by the political, economic, social, technological, environmental, and legal (PESTEL) conditions. The authors did caution that the study was limited to highway concessions only, but other sectors such as public/social housing and water/wastewater projects might have told a different story.

2.4 Theoretical Development of Innovations in P3s

There are many theoretical developments for construction innovations in general. Different innovation frameworks have been developed from various perspectives. For example, Rose and Manley (2012, 2014) presented a model to characterize the diffusion of innovations from the industry perspective. Mohamed and AbouRizk (2005) proposed a systematic approach to creating innovative solutions in construction projects. However, of interest here are studies that look at theoretical frameworks at the project level from a particular project delivery system perspective. Three important pieces of research with this focus are reviewed below.

Is innovation a function of the procurement model? Can we characterize the innovation potential of a P3 project? These are the questions that Russel and his research team asked (Russell et al., 2006; Tawiah & Russell, 2008). From a public authority’s perspective, they identified 22 factors that were further grouped into the five categories: project-specific characteristics, commercial and business factors, project requirements, project risks, and socio-economic and political considerations. The key message of the study is that clearly Ps3 provide no guarantee for a project environment that encourages innovation. The majority of the factors serve as both a driver and an inhibitor of innovation. Their actual effect would really depend upon how they are controlled in practice. For example, greater responsibility integration may lead to a higher potential for efficiency and innovation. However, responsibility integration of a project team, which is a temporary organization by nature, is always a difficult issue. Although P3s have lessened the severity of the temporality of the project organization, the actual degree and extent of integration depends upon several factors, including the contractual arrangements of design, build and maintenance, and human dynamics. The last factor is important for any procurement model.

Leiringer (2006) provided great insights into the relationship between P3s and innovation. He refuted the face values of four common rhetorical arguments, which P3 advocates often use to promote the model as an incubator of innovation. The four arguments are design freedom, collaborative working, risk transfer, and long-term commitment. Regarding design freedom, he cautioned about the difficulty in writing a good output specification. In his opinion, a good output specification must be flexible in technical solutions and yet firm on performance or service targets. This creative tension would provide a clear compliance boundary in order for the private partner to construct a sound technical space before selecting the most innovative solutions. In face of this real difficulty, he emphasized the importance of effective communication between the public sector client, the project company, and the end users during the entire procurement process. Moreover, what the flexible output specifications provide are opportunities for the private players to perform the specific tasks in a way that best suits their expertise with the most competitive advantage. This point is really insightful as it answers the question of why only incremental innovations are observed in P3s.

As far as collaborative working is concerned, Leiriniger noted that the project agreement in a P3 involves a large number of stringent, interlocking contracts that would force the involved parties to go out of their way to establish routines that effectively countered the restrictions in collaborative working forced upon them by the stringent contracts.

Risk transfer per se does not lead to innovative behaviour on the project; rather, it is the greater clarity of where the risks have been allocated that might prove beneficial for innovative efforts.

Finally, the long-term commitment itself does not necessarily help private sector actors produce a lifecycle cost minimized product. Rather, the earlier involvement of operation and maintenance providers is paramount in order for them to provide input into the design and construction solutions.

Davies and Salter (2006) examined the impact of P3s on the innovation process from an organization theory perspective. They argued that the P3s have forced the construction industry to refocus on the system integration capacity in order to reposition itself in the value stream from material supply through design and construction operation service provision. They warned that, without a high level of system integration between different stages of design, construction, operation, and maintenance of the built facilities, the use of P3s would have shifted the separation of these stages from the government to the private sector, and there would be few opportunities for technological innovation to be materialized.

2.5 Procurement Strategies for Innovation in Canadian P3s

It is in the general interest of public procurers through the P3 or AFP model to incorporate private sector innovation and expertise to deliver a competitively priced effective facility that demonstrates superior design, construction, operation, and maintenance. The particular strategy for innovation adopted in the procurement process is stipulated by the RFP documents. A procurement strategy for innovation can be characterized by the encouragement of innovation submissions, timeline of submissions, and evaluation criteria of the innovation submissions. The Provinces of Alberta, British Columbia, and Ontario have used P3s/AFP extensively and they have standardized their procurement process over the years. Their practices are the focus of this part of review. For that purpose, the research team scanned the RFP documents that were available on the provinces' websites.

2.5.1 Infrastructure Ontario's Practice

The particular strategy for innovation adopted in IO's AFP model has undergone little substantial change, except for the change in the use of terms for innovation submissions and the fact that the submission and evaluation processes have been streamlined. The review of the evaluation criteria was constrained by accessibility to some key documents of the RFP materials (e.g., Schedule 3 – Submission Requirements and Evaluation Criteria). Nevertheless, the summary does show the general maturity path of IO in the procurement for innovation through the AFP. Three representative P3 projects at different stages of maturity are reviewed.

Durham Consolidated Courthouse (2006). There are two concepts in the RFP document of the Durham Consolidated Courthouse project that are related to innovation, i.e., Bid Enhancement Factors and Alternative Proposals. In comparison with the base proposal, which must satisfy all provisions of the PSOS, an Alternative Proposal is submitted, in addition to and after the submission of the base proposal. The Alternative Proposal outlines how it will

- Achieve one or many of the bid enhancement factors that are stipulated in the RFP
- Depart from the PSOS
- Deviate from the risk allocation schemes set out in the project agreement, or
- Include any combination of the above

According to the RFP, a Bid Enhancement Factor is a value-added solution to one of the following three identified areas: energy performance, LEED Gold certification, and lifelong LEED-recertification, and other value-added enhancements that are within the scope of the PSOS.

Under this framework, it seems that a proponent has the opportunity to propose innovative solutions within the defined innovation areas, beyond the defined area but within the work scope, and even beyond the work scope. For the latter case, the RFP stipulates that the proponent must obtain the explicit permission of the public sponsor in advance of such development.

In addition, the RFP requires that "no Alternative Proposal submitted shall result in an increase in the overall NPV cost of the Project by greater than 2% over that Proponent's Base Proposal." It adds that any alternative proposal that exceeds such limit may be rejected.

In terms of evaluation of the enhancement factors, the RFP states that "any innovative approach to the design or maintenance of the DCC will be evaluated on its demonstrated value." The RFP includes a description of the opportunity to earn evaluation bonus points, which is described in an appendix of the RFP, but unfortunately the appendix is not accessible to the researcher.

The RFP also includes a paragraph regarding the confidentiality of innovation in the RFP stage:

> *If a Proponent believes it has a unique and innovative Alternative which is unlikely to be known, discovered or considered by other Proponents and if the Proponent wishes [IO] to keep the potential Alternative confidential then, when requesting an indication from [IO] as to whether the Alternative Proposal may be of interest to the IO, the Proponent must expressly state in its request that it wishes IO to treat the inquiry as confidential.*

Bridgepoint Hospital (2008). The RFP of the Bridgepoint Hospital project uses two different terms to define the technical innovations that the proponent might submit: the Required Innovation Submissions and Innovation Submissions. Confusing as they are, the former refers to those areas for which the public sponsors wish the proponents would provide innovative solutions, whereas the Innovation Submissions are more free-hand value-added proposals. Therefore, the Required Innovation Submissions correspond to the first three Bid Enhance Factors in the Durham Consolidated Courthouse project, and the Innovation Submissions correspond to the last value-added enhancements that are within the scope of the work. In the Bridgepoint Hospital RFP, however, both of the innovation submissions are submitted as a part of the proposal rather than as a separate parallel proposal as required in the Durham Consolidated Courthouse project. Clearly, this is a result of the continuous procurement improvement process adopted by IO.

Pan Am Athletes' Village (2011). The RFP calls for three separate innovation submissions:

- Preferred innovation submissions
- Innovation submissions
- Innovation submission (sustainable energy)

The reason that the procurer identified sustainable energy as a separate innovation item was not very clear. However, further scanning of RFPs of more recent AFPs indicates that the IO has standardized the use of the two terms, using preferred innovation submissions for solicited innovations and innovation submissions for unsolicited ones.

2.5.2 Partnerships BC's Practice

Partnerships BC is mandated to support the public sector in meeting its infrastructure needs in the procurement of complex capital projects by utilizing private sector innovation, services, and capital to deliver measureable benefits to the taxpayers. Several P3 RFP documents (e.g., Abbotsford Hospital and Cancer Centre, 2003; Sea to Sky Highway, 2004; and South Fraser Perimeter Road, 2009) were reviewed. Unlike IO, Partnerships BC has been using the same term of alternative proposal for innovation submissions. Another interesting point is that Partnerships BC has been very fluid in terms of the scope of innovation. Many of its RFPs include only one paragraph that reads like this: "To promote innovation, Proponents are encouraged to develop Proposals that differ or vary from the Reference Concept and that comply with the requirements of the Concession Agreement."

2.5.3 Alberta's Practice

Alberta's P3 model takes an explicit lowest bid principle in the selection of the preferred proponent. In its P3 Framework and Guideline document, the Alberta Treasury Board (2011) states that "the compliant bidder submitting the lowest bid, on a net present value basis, is the Preferred Proponent." It further adds that this evaluation method may only be modified where there is significant value to be derived from innovation. Starting with five ring roads in Edmonton and Calgary, Alberta's P3s have recently moved to school projects. The review of the process of procurement for innovation covers both transportation projects and school projects.

Southeastern Anthony Henday Road (2004). The selection of the preferred proponent in this project's RFP consists of three mandatory submissions (SR Packages 1, 2, and 3) in different stages. The three mandatory submissions address management plans, technical solutions, and financial solutions, respectively. Prior to the submission of SR Package 1, the proponents are encouraged to submit an optional innovation submission that includes innovative design solutions for early feedback by the public sponsor as to their likely acceptability. The proponents are often given about one month to prepare and submit the innovative solutions. In response to such submissions, the procurer will attempt to provide written feedback separately to each participating proponent, within two weeks of the deadline for the optional innovation submission. Such innovative solutions are still required to meet the functionality requirements. The information provided should be in sufficient detail to allow the department to understand how the proponent's innovative solutions depart from the solutions in the functional plan and how the proponent's innovative solutions nevertheless satisfy the functionality requirements. The department will not share the contents of the optional innovation submissions or of the corresponding feedback with any other proponents. However, the department reserves the right to issue an addendum or otherwise amend any aspect of the RFP on the basis of information it receives through the optional innovation submission process.

Southeastern Stoney Trail (2009). The RFP submission requirements and selection process are very similar to the earlier Southeastern Antony Henday Road project. A noticeable difference is that in this project, the proponents are given a slightly longer period to prepare the optional innovation submission. The submission deadline was actually between the submission of SR Packages 1 (management plan) and 2 (technical solutions).

Phase 1 – 18 Schools (2008). The submission requirements and selection process in the RFP are almost identical to those for the Southeastern Stoney Trail project. This shows that by 2008 Alberta had standardized the P3 procurement process.

To summarize, different P3 procurers take slightly different ways to encourage innovations from the private partners. While the Provinces British Columbia and Alberta procurers use fairly loose terms to entice the proponents, the Province of Ontario often provides explicit signals for innovation in the RFP documents through the invitation of submitting the so-called required or preferred innovation submissions. It would be interesting to evaluate how this procurement strategy affects the adoption of innovation in practice.

2.6 Concluding Remarks

The literature review has set up a good context for the subsequent interviews. Although many definitions have been considered in literature and there seems to be a trend to agree that "novel to the organization" and "actual use" are the two essential characteristics of innovations, the context of innovations (e.g., the driving forces, the embedded risk, and the learning curve of one organization using the innovation) is an important factor in defining innovations.

The construction industry in general is not considered as an innovative leader. Statistics show that the Canadian construction industry is lagging behind many developed countries such as the UK and the USA. One contributor to this is the lack of R&D in the industry.

Meanwhile, Canadian P3s have generally been seen to deliver public infrastructure on time and on budget. The innovation record of Canadian P3s also seems very promising. However, literature based on British PFI practices seems to provide conflicting evidence: some claimed very positive experience of innovation in P3s, whereas others expressed fairly pessimistic views.

Thus, the P3 procurement itself does not seem to be a guarantee for innovation. A number of theoretical studies have tried to formalize some kind of analytical framework to explain and guide construction innovation, but it remains a difficult task to disentangle the precise effect of the project delivery model on the performance of the project. Therefore, the key question we hope to answer in this study through the interviews and discussion and that will help us to better understand the effects of P3s on engineering innovations is not *whether* P3s encourage innovation but *how*. The literature review has suggested key areas that are worth investigating further. They are: output specifications, innovation champions, procurement process (including the timeline, evaluation of innovation submissions and/or alternative proposals, and post-selection negotiations), and responsibility integration.

3 Interview Results and Discussions

This section summarizes the major findings from the interviews using interpretation or discussion. The section is organized in the way that it addresses the *what, who, when, why,* and *how* questions about innovation in P3s. It begins, however, with a brief description of the interview program.

3.1 The Interview Program

The objective of the interviews is to understand how the notion of innovation is perceived by the industry; what, when, why, and where innovative solutions have been used; and to identify the factors that led to the innovation being implemented. For this purpose, a series of interview questions were designed based on the major findings from the literature review on engineering innovation. The original plan was to interview up to 20 people, made up of public procurers, private partners, and end users. Three separate sets of interview questions were designed; refer to Appendix B for the details of the questions.

In planning the interviews, we identified at least three potential interviewees for each project. However, due to time constraints and scheduling conflicts, only 19 interviewees finally participated in the study. These interviews covered 15 of the 19 P3 projects listed in Appendix A. For the sake of confidentiality and privacy, the list of interviewees is not included in the report.

The findings presented below are drawn from the interviews of the 19 interviewees who include public clients, procurement authorities, investment groups, general contractors, engineering consultants, and facility managers.

3.2 What Is Innovation?

The first question of the interview relates to the definition of innovation. What does innovation mean to you? Although the specific responses are different, interviewees generally agreed that innovation means a product, process, or method that the proponents use to maintain the competitive advantage and differentiate themselves from the other competing bidders to win the job. It refers to not only new ideas, but also to the existing ideas that are used in different projects.

One interviewee emphasized the learning curve context of innovation. In particular, any innovation takes a learning process and often numerous applications, for an innovator to get to a comfort level before the innovation turns to a routine use. Until this comfort level is reached, the application of the product, technology, and process can be considered an innovation. Examples of such innovations that are now normally used are: quick movable barriers, rapid bridge replacement, and roundabouts in transportation projects, and green roofs in building projects.

Another interviewee pointed out that there are two levels of definition. At the macro level, because each project is unique, it must be innovative by nature. At the micro level, there are many innovations in the means and methods, which are routinely observed in almost every infrastructure projects, whether delivered by P3s or not. Clearly our interest is in those innovations that have less opportunity to appear in traditional delivery models.

Comparing the interview results with those definitions from the literature review, we found that the industrial perceptions of innovation to be very pragmatic:

1. Innovation does not have to be brand new even to the organization that proposes it. But it has to be different than the client's solution. Preferably, the solution should have a competitive advantage over the competing proponents.
2. For proponents, innovation is more about winning the bid and getting the job done than achieving efficiency. Efficiency is gained indeed where innovations are implemented, but this is more of a derived term.
3. For public procurers, innovation is mainly about cost saving. Because many other factors are to be discussed subsequently, non-cost saving innovations are hard to be accepted.

These pragmatic views of innovation are very important to understanding the disparate assessments in the literature regarding the extent to which innovations are used in P3s.

3.3 What Innovations Were Used?

A great variety of engineering and technological innovations were adopted in the P3 projects discussed in the interviews. Many interviewees could identify at least three major innovations for each project they participated in. The details of the major innovations identified during the interviews are presented in **Table 5**, **Table 6** and **Table 7** for social/justice, healthcare, and transportation/transit P3s, respectively. Note that during the interviews the interviewees were not requested to provide the full list of innovations the P3 project had introduced; rather they were only encouraged to identify the major innovations that they felt most significant to the project success. For some projects, the interviewee or the organization the interviewee was associated with had already prepared a written document about innovations, in which the list appeared to be more complete. Therefore, it is inappropriate to compare the absolute number of innovations between projects or infrastructure sectors. Our major interest is to show the nature of innovations.

Following the innovation classification system of Slaughter (1998) that has been explained in Section 2, we have tried to identify the category of each innovation and the results are also shown in the last column of **Table 5**, **Table 6** and **Table 7**. It is admitted that the classification may be subject to judgment error. The summary statistics of the identified innovations are presented in **Table 8**. About 60% of the innovations belong to the incremental innovation category, and this percentage does not vary significantly across the three infrastructure sectors. The modular, architectural, and system innovations take more or less equal share, ranging from 10% to 14%, of the total innovations. No innovation identified in the interviews is qualified for a radical innovation.

Examining in more details of the identified innovations, one can readily observe a common trend. That is, for P3s of the same sector, some innovations tend to occur repetitively. For example, clinical layout design that results in reduced sneaker time were reported in several hospital projects. Bridge projects often involve innovations in cross-section design to respond to requirements for height clearance, need of cost reduction, and considerations of constructability. Open-cut excavation construction was identified to be an innovative solution, in lieu of bored tunneling, in a number of tunnel works. Innovative traffic management strategy was also repetitively reported as an innovation for transportation and transit projects. This repetitive occurrence of the same solution seems paradoxical for innovation, as many people would argue that new and unique are the defining features. However, as many interviewees argued, and we absolutely agree, all of those innovations identified were alternate solutions to the reference design. They were brought up either to enhance the quality and performance of the facility designed or to meet certain specific project challenges (schedules, traffic congestion, environmental regulations, etc.). Moreover, although many innovations are called the same name (e.g., open-cut excavation, haunched girders), the exact technical solutions can be very different because the implementation of the solutions have to fit in the project contexts. This is very different than a simple plug-and-use of a certain new product. System integration is the essence of engineering design and construction, and it is through the integration that innovation arises.

Table 5: The major innovations identified by interviewees – social/justice projects

Project	Innovations Identified by Interviewees	Type
Durham Consolidated Courthouse	1. Strategies for energy conservation (compact footprint, building orientation, use of spandrel glass panels, etc.)	A
	2. Strategies for resource conservation (construction waste reduction, rainwater harvesting and cistern system, flexibility in room use and expansion, etc.)	I
	3. Use of cementitious terrazzo for long-life flooring (higher upfront cost versus lower lifecycle cost)	I
	4. Use of ultra-low flow plumbing fixtures	I
	5. Audio/video system, acoustic system design for the simultaneous interpretation room	I
	6. All rooms wheel-chair accessible	I
OPP Modernization Project	1. Successful coordination of 18 sites dispersed throughout the province, use of local trades and building materials, all 18 facilities certified with LEED Silver	A
	2. High-security buildings with progressive collapse design considerations to withstand earthquakes	M
Toronto South Detention Centre	1. Use of geothermal ground source heat exchanger, resulting in 40% reduction in natural gas consumption in the facility	A
	2. Use of low-flow technology that reduce 20% water usage	I
	3. Use of module construction technology for the design and construction of prefabricated detention cells	M
	4. State-of-the-art building automation system	I
	5. Programmable lighting control	I

Pan Am Athletes' Village	1. Adoption of the 'cohesive diversity' principle during architecture design	I
	2. Environmental remediation and implementation of risk management measures	A
	3. Mix of residential facilities providing accommodation for athletes and officials and administrative and support facilities	A
	4. Conversion of the village back to market-ready Legacy uses	S
	5. Intelligent community network with low cost gigabit broadband service	I

Table 6: The major innovations identified by interviewees – healthcare projects

Project	Innovations Identified by Interviewees	Type
Niagara Health System	1. Clinical layout design by using decentralized nurse units to optimize the service distance	I
	2. Public circulation design that reduced construction cost and enlarge useful space	I
	3. Increase in thickness of a roof layer that result in a better product and less planned replacement over the life of the contract	I
	4. Above-specification design and adoption of electronic doors to reduce damage and consequently the total lifecycle cost	I
Bridgepoint Health	1. Wall protection system: introducing a new material that makes the wall system seamless, housekeeping and maintenance became easier and more cost efficient.	I
	2. Reclamation of the bricks in the existing building	I
	3. Adoption of a new type of oxygen tanks	I
Humber River Regional Hospital	1. Modular patient washroom and telecom rooms and standardize the design to reduce cost	M
	2. Change the old fluorescent light bulbs to LED lights	I
	3. Adoption of a real-time deficiency monitoring devices to increase work efficiency	I
	4. Lean clinical layout design for less sneaker time and easy access to portals of care	I
	5. Use of pneumatic tube system and automatic guided vehicles, 75% deliveries by automation	M
	6. RFID for patient flow and staff	I
	7. RTLS for safety and security enhancement	I
	8. Integrated bedside terminals	M
	9. Electrochromic glass for adaptive view, energy conservation, and ease of maintenance	S
	10. 100% fresh air circulation	S
Women's College Hospital†	1. The first multi-phased social infrastructure project to be procured and managed by Infrastructure Ontario	A
	2. Minimize disruption in downtown Toronto during construction period	I

† The Women's College Hospital project is still under construction and more innovations are expected to occur as construction proceeds.

Table 7: The major innovations identified by interviewees – transportation/transit projects

Project	Innovations Identified by Interviewees	Type
Canada Line	1. Use of cut and cover tunnel instead of bored tunnels on Cambie Street	I
	2. Innovative alignment design to avoid relocation of box culvert	I
	3. An extradosed bridge design instead of a segmental haunched box girder	I
	4. Use of modified Frankie piles for a liquefiable sand/silt ground	I
	5. Single-track guideways at Richmond and YVR terminus, where the ROW was very constrained	I
	6. Use of construction joints in guideway tunnels to eliminate the need of preloading the site	I
	7. Centre platform station design, rather than a side platform design	I
	8. Relocating the guideway of Number 3 Road in Richmond	I
	9. Without preselecting the train supplier by the owner, the Contractor acted as the train systems designer/integrator	A
Sea-to-Sky Highway	1. Innovative design management for 'on the fly' design to respond to highly variable site-specific bedrock profile	A
	2. Collaborative design-build for traffic management	A
	3. Hybrid CIP/MSE retaining walls	M
	4. The extensive use of semi-integral abutments and elimination of deck joints to ensure durable and long-lasting structures	I
	5. Use of partial-depth precast concrete deck panels	I
Disraeli Bridges	1. River bank stabilization during winter season	I
	2. Bridge design, lane closure and traffic management plan: 1) built two new bridges adjacent to the existing ones by changing the alignment; 2) phased opening of lanes: 4 lanes in the old bridge, 2 lanes in the old bridge and 2 lanes in the new bridge, and all 4 lanes in the new bridge	A
	3. Winter construction method or construction within a limited time window	M
	4. Contamination containment plan, including the layout of bridge piers, and some other treatment to minimize the impact to ecology such as fish habitat	I
	5. Reuse the existing vehicular bridge to build a new active transportation bridge	S
Anthony Henday Drive SE	1. Fast track environmental permitting	S
	2. Reconfiguration of a service interchange layout to solve the traffic weaving distance requirements	S
	3. Use of a kinked girder in lieu of a curved girder for the third-level bridge structure	M
	4. A haunched girder design over the railway portion of the bridge	I
	5. High skew bridge design instead of a trellis bridge in the reference design	M
	6. Lightweight fill to avoid utility relocation	I
	7. An interconnected system of naturalized ponds resulted from earth borrowing to enhance stormwater management.	A

	8. Introduction of Ontario illumination wiring techniques to Alberta	I

Table 7 (continued)

Project	Innovations Identified by Interviewees	Type
The Rt. Hon. Herb Gray Parkway	1. NU bridge girders (approved for use in Ontario for the first time)	I
	2. Cementrix (foamed cement), used as lightweight backfill for RSS retaining walls (first time used for this application in Ontario)	I
	3. Vertical profile optimization to minimize costs	S
Ottawa LRT (Confederation Line) †	1. Use of a proprietary Petrucco box construction technology to avoid interrupting adjacent train traffic	M
	2. Alternative BRT detour alignment at Nicholas St.	A
Highway 407 East Phase 1‡	1. Use of NU girders	I
	2. Vertical profile optimization	S
	3. Reversed stacking of 401/407 interchange from reference design	I
	4. Change in foundation type, from pile to spread footings	I
	5. Shift of side road alignment to avoid utility relocations	I
	6. New safety barrier used for the first time in Ontario	I
	7. New water-proofing material for bridge decks	I
	8. Elimination of Open Grade Drainage Layer (OGDL) in pavement structural design	I

‡ Both Ottawa LRT project and Highway 407 East Extension (Phase 1) project are under construction and more innovations are expected to occur in the two projects as construction proceeds.

Table 8: Summary statistics of identified innovations

Innovation Classification	Number of Applications			Total
	Social/Justice	Healthcare	Transportation/Transit	
Incremental (I)	10	13	24	**48**
Modular (M)	2	3	5	**10**
Architectural (A)	4	1	6	**11**
System (S)	2	2	5	**8**
Radical (R)	0	0	0	**0**
Innovations Subtotal	**18**	**19**	**40**	**77**
Projects Subtotal	**4**	**4**	**7**	**15**

For a few P3 projects, for which different players in the private sectors (e.g., the investor, the D/E team, and facility manager) were interviewed, the same innovative solutions were identified by the interviewees from the different groups. However, we also found that sometimes the public client and the project proponent of a same project had different lists of innovations. This shows that the same innovative solution has different and varying effects on different stakeholders.

It is worth noting that Slaughter's innovation classification mainly emphasizes the effort of management coordination involved in the process of innovation, but not the impacts of innovation. Therefore, the impact of an incremental innovation is not necessarily smaller than that of a system innovation.

A few interviewees (from private sector or with extensive private sector experience) explicitly pointed out that the strength of P3s has to be in the innovation of system and process integration. By that it means that the whole project team (design, construction, and operations and maintenance) should work together to find an optimal solution from the lifecycle cost perspective. The use of electrochromic glass windows in the Humber River Regional Hospital project is such an example. Although it appears at first sight to be only a simple adoption of a new product and thus it might be only qualified for an incremental innovation, the interviewees from both public and private sectors agreed that the solution was a result of collaborative work involving architects, materials engineers, energy consultants, and facility managers. The new window product triggered a reevaluation of the whole system's energy performance. Several iterations of system reengineering had been carried out before the system performance was optimized. In the end, the solution provided a number of positive impacts: an adaptive view, energy conservation, and ease of maintenance.

In terms of impacts that the innovations have caused, a great variety of impacts were reported during the interviews, including lifecycle cost reduction, energy and resource conservation, schedule compression, performance enhancement, reduction in traffic disruption, ease of maintenance, and better quality management. For transportation and transit P3 projects particularly, several interviewees pointed out that a 20 to 30 percent cost reduction was observed in comparison with traditional delivery methods. They argued that some of the cost reduction was due to innovation and efficacy in delivery, and other factors (such as bidding competition) made up the balance of the difference.

3.4 Who Was Leading Innovations?

Literature seems to suggest that clients should play a pivotal role in leading construction innovation. However, under the high competition pressure and expensive proposal preparation, all of the interviewees from the private sector stated that they were actively involved in the preparation of innovation submissions or alternative proposals. All of the interviewees from engineering firms and who were general contractors confirmed that innovations never stop until the completion of the project.

As discussed in Section 2, Infrastructure Ontario uses preferred or required innovation submissions to encourage private partners to prepare innovative and competitive proposals. The interviews indicated that in the majority of cases the proponents responded proactively to the preferred innovation submissions. The scope of the preferred innovation or enhancements that were suggested in the P3 projects was extensive, examples being sustainability (energy and water consumptions, waste reduction, and other green initiatives), flexibility, adaptability, and revenue-generating opportunities. For those preferred innovation items, the public procurers could be considered the champion of the innovations.

Several interviewees from Ontario suggested that the innovation submission requirements be removed in the new round of RFP template improvements because this requirement has not resulted in many positive outcomes in previous procurements, except for prolonging the proposal evaluation period. But interviewees from an infrastructure investment company indicated clearly that they always make great efforts to satisfy this submission requirement in order to win the job. Note that P3s in the Provinces of British Columbia, Alberta, and the City of Winnipeg usually do not specify any focused area of innovation. However, the interviews with people who worked on projects from those provinces did not express the need for a guided innovation area. But it was hard for us to assess whether the client's identified areas for innovation would encourage innovation or not, because this question appeared fairly late in the interview program. This may be an interesting question to investigate more fully in a future study.

3.5 When Did Innovations Occur?

As to when innovations occurred[1], different views were received from the interviewees:

- Some said 80% of the innovations occurred in the RFP stage.
- Some said the majority of the innovations occurred during the implementation stage, including the schematic design and construction planning stages.

This difference probably can be attributed to the sector difference (c.f. Table 5, Table 6 and Table 7). People from building (social/justice and healthcare) projects tended to hold the former opinion, whereas the people working on transportation and transit projects agreed more to the latter. One interviewee pointed out that the technical scope of innovation during the RFP stage in transportation and transit projects was constrained by previous public consultation and commitments, previously-secured environmental approvals, and strict technical standards and specifications applicable to the work. However, in the construction stage, the uncertain subsurface conditions in these types of projects forced private partners to deliver innovatively. The innovations in Rt. Hon. Herb Gray Parkway project and the Highway 407 East Phase 1 project identified by interviewees occurred almost during construction stage. However, when it comes to innovations in the building projects, such as the use of modular patient washroom and telecom rooms in Humber River Regional Hospital project and conversion of the village back to market-ready legacy uses in Pan Am Athletes' Village project, the innovative ideas were brought up during RFP stage. Reviewing an MMM Group document that collected the major innovations adopted in a number of transportation and transit P3s in Canada and the USA, some of which were also part of the projects identified for the interview program, we found many innovations were initiated during the construction stage. This indeed shows the effectiveness of P3s in

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[1] Here the occurrence of innovations refers to the event in which the ideas of the innovative solutions are brought up and approved. Implementation of the approved solutions can happen later.

transferring risks that the public would have to take responsibility for in a more traditional delivery mode.

3.6 Why Were Innovations Proposed and Adopted?

A number of motivations were given by interviewees from the private sector for the reason innovations were proposed. These motivations can be classified into the following two simple groups, depending upon when the innovation was proposed:

- To win the bid (or to get the job)
    - To satisfy the submission requirements (innovation and preferred innovation submission)
    - To satisfy the PSOS requirements (e.g., LEED requirements, energy saving requirements)
    - To reduce the lifecycle cost
    - To maximize or optimize the system performance
- To get the job done (in addition to the motivations mentioned above to win the job)
    - To fit the actual site conditions
    - To adapt to the most recent technological change
    - To meet constructability requirements

The evaluation and acceptance criteria also varied. Among them, cost saving, performance enhancements, and certainty in asset and service delivery were the most-often used reasons. There were also many factors contributing to unacceptance of innovation submissions. For each innovation or alternative proposal, bidders were required to quantify the specific NPV benefit and any associated changes relative to the RFP, the project agreement and the project works. A performance enhancement innovation item without significant increase in the cost was more readily accepted. Otherwise, it was often rejected for reasons of affordability. Meanwhile, proponents were also required to provide clear, strong, and firm evidence for the validity of the innovative solutions. Weak and vague evidence often resulted in rejection of the innovation proposal. This also discouraged the private sector to try out untested solutions in P3s.

Two key factors were identified as influencing the decision of whether to adopt or reject a particular innovative solution:

1. The time constraint and information provided. There was a very tight bid evaluation period. This dictated that the innovation must have been demonstrated and proof tested by others in some other projects in some jurisdiction. Many innovations were rejected because there was lack of in-depth information about the solutions for the procurer to make an acceptance decision.
2. Consideration of safety, reputation, and residual value risks. Although most of the cost risks in a P3 have been transferred to the private sector, public procurers still have to take into considerations those implicit risks (safety, reputation, durability, or residual

value risks) that the innovation might induce. Therefore, cost (even lifecycle cost) and performance were not the sole criteria considered in the decision. It has to be noted that although there is some level of risk aversion by public authorities, engineering innovations occurred and are still occurring, albeit in not such an accelerated way as they might otherwise be seen in P3s.

3.7 How Can Innovations Be Further Encouraged?

Each interview ended with this last open-ended question: How can innovations be further encouraged in a P3? Better performance-based output specifications, improved communications across the project stakeholders, and enhanced system integration were the top three answers. A few other improvement suggestions are discussed below.

3.7.1 Output Specifications

The majority of the private sector interviewees suggested that the PSOS should include more performance-based specifications. However, two interviewees insisted that there were benefits to the rigid, product/materials-based specifications, particularly when there would be a slim opportunity for alternatives solutions. According to those two interviewees, a prescriptive specification was clear, straightforward, and thus free of interpretation risks.

Many public sector interviewees also agreed that the PSOS should be less prescriptive. However, they also stressed the difficulty of writing a good performance-based output specification. One interviewee used the following analogy to describe the subtlety of PSOS writing:

> *Writing a PSOS is like setting a stick point in the ground when leashing your puppy in the backyard; once the stick point is set, your puppy would only be able to walk around the stick point. The objective is to give your puppy the largest space that it can walk around. However, often we found that the stick point wasn't optimally set to give the puppy the largest space. There are flower beds you don't wish the puppy to fuss about; there are fences that the puppy cannot pass; and so on and so forth. Considering all of those constraints (in project setting, these are the regulatory limits and engineering standards, codes, specifications, etc., also called non-negotiable constraints), we may find ourselves setting the stick point in the corner of the backyard, as this might be the most comfortable place to avoid additional trouble. This also brings up an ethical challenge for PSOS writers.*

In addition to the PSOS, many public procurers prepare a reference design and/or an exemplar design to complement the project requirements and expectations. Although the procurers also emphasize that the proponents were encouraged to deviate from the reference design in the RFP, one interviewee rightly warned, "Architects/engineers often cannot avoid their bias toward the reference design." This kind of "anchoring effect" clearly impedes innovations.

Another interviewee from the public sector had a more pragmatic view of the challenge of PSOS writing:

> *The major challenge in developing output specifications is that sponsors often tend to wish to have predictable outcomes. The experience of the PSOS writer (a team of architects, engineering consultants, and facility managers) is very critical to the success of the PSOS. Don't forget that the writing team are the people who might have worked on the private sector in other projects. Those people know the tricks that the builders would play in the field and sometimes they tend to overreact by over-specifying.*

Nevertheless, as another interviewee shared about his experience, being a bit less pragmatic was a good practice:

> *Even when the writing team felt that there should be only one technology that would be able to deliver that particular function, [we thought] let's just be open, even pretentiously. Who knows? You may get some surprises. And you know what? We did get surprises in previous projects! Those are true innovations.*

The track record has not been very good in accepting innovations. More than a dozen innovation items were typically submitted in an AFP project, and yet only a few were accepted. Considering the drawbacks of the non-compliance innovation submission model, IO is practising a new model called the output specification white paper model. During the proposal preparation stage, the shortlisted proponents are invited to review together the PSOS and submit their comments. Meanwhile, IO also holds workshop to explain the non-negotiable constraints (why they are necessary, how they are determined, etc.). Based on the feedback, IO and the sponsor revise the PSOS and then the proponents proceed with the preparation of their proposals. The effectiveness of the white paper model has yet to be assessed, but an IO official interviewed in this study confirmed that the model has so far been "well embraced" by the industry.

3.7.2 Communications

About a half of the interviewees stressed the importance of effective communications in innovations. Effective communication is important in many situations:

- As mentioned above, PSOS writing is challenging and the two traits of specifications – flexibility and precision – are hard to reconciled. This requires effective communications between the public procurer and end users. End-user group meetings should be conducted before and during the RFP stage.
- Within the project company, the design-build-service group needs effective communications in order for innovations to occur. As one interviewee from a general contracting firm rightly claimed: "Communication is the generator of innovation." A general contractor's expertise in advanced construction technology and constructability issues and a facility manager's operation and maintenance experience can only be imparted to the designers through in-depth collaborative work.

3.7.3 System Integration

An interviewee who was a public procurer and who had many years of consulting experience commented that there was much room for the consulting and construction industry to learn how to work more closely together. According to him, many project companies still do not have an effective internal organization chart in their design-build team, and thus the design practice in those P3 projects has not had much difference in the traditional delivery model, except the design engineers worked for the project company instead of the client. Therefore, innovations through system integration requires more effective communication and design management. Some successful project companies have very strong design-build team who can deliver the so-called "On the Fly" design (a term used to describe the just-in-time design in civil infrastructure projects in which design drawings are delivered within a week of receiving detailed geotechnical survey results from construction site). However, the whole design-build industry has yet to elevate itself to meet the system integration challenges in P3s.

Another interview with a facility manager confirmed that the integration of lifecycle solutions can be further improved in P3s.

3.7.4 Other Tactics

Interviewees suggested other factors that could further improve the current procurement process.

Evaluation Criteria: Several interviewees from the private sector criticized the heavy weight on cost in proposal evaluation. According to them, as the public procurers standardize their procurement process, one has to be careful that too much weight on cost will kill the motivation for "genuine innovation." Another suggestion heard during the interviews was related to hospital projects. In particular, it was suggested that the scope of the evaluation be expanded from the building infrastructure to include the functional serviceability, e.g., the ease of clinical operation, medical operation costs, and so on.

Another insightful recommendation came from an interviewee retired from a public procuring agency. He suggested that we should think of some innovative mechanism in procurement to encourage the proponents to bring forth innovative solutions, while still reserving the rights to add those solutions to the project specifications as addenda during the RFP stage. One way to do this, he suggested, may be that "we provide certain credibility for those innovative solutions that the clients have decided to add into the project specifications."

Time Constraints: Several interviewees from both the public and private sectors mentioned that innovations were sometimes constrained by the time limits of proposal preparation. Proponents were given very limited time to fully develop ideas and solutions. This resulted in their having less of a chance to communicate with the public procurers properly. In order to be competitive, many engineering firms took "design standardization" as the powerful tactic to offer just-in-time design. Design and construction standardizations are powerful tactics of innovation, indeed. But they may also limit the scope of innovation in reality.

Bid Cost Compensation: When asked if the design and bid fee (exercised in IO's AFP) plays any role in encouraging innovation, an interviewee from a private partner responded very positively. With the fee providing some compensation to mitigate losses, more effort can be applied to look for alternative solutions that provide value to the client and not just meet the base requirements. Nevertheless, the respondent also added that the amount of the design and bid fee could never make up the loss of losing the bid.

Confidentiality: One interviewee suggested that keeping innovations confidential during the projects would encourage the private sector to use innovative methods.

3.8 Comparison of P3s with Traditional Delivery Models

In the comparison of P3s with traditional delivery models, interviewees provided many insights from their first-hand experience. Whether from the public or private sector, the interviewees all agreed that P3s provide better opportunity and more scope for innovation. No one from the interviews expressed any doubt about this.

When asked why he would agree with this, one interviewee who worked in a hospital project elaborated as follows:

> *In the traditional project delivery of design-bid-build, the architect often plays a pivotal and leadership role in design, while other engineers, consultants, contractor and subcontractors, more or less, just accommodate or consolidate, and implement the design ideas that the architect has put forward. Thus the relationship between architects, engineers, and contractors is fairly hierarchical. The facility management professional is even left fairly isolated, except for probably in the early project development stage where only diligent clients may consult their own facility manager for operational inputs. In contrast, P3s require that the architects, engineers, contractors, facility managers, and other consultants work more integrally. The relationship between these key players is very horizontal. To provide a viable innovative solution, all disciplines and the client (including user groups) have to work together and undergo several rounds of solution iterations. From a general contractor's perspective in particular, P3s require that the contractor be a thinker and a solution provider, rather than simply an implementer.*

A public sector interviewee supported this view from another angle. He argued that in a traditional DBB, the client would receive only one design, but in a P3, the client would receive four!

The interviews also tried to compare the P3s with other delivery models such as design-build (DB) and construction management at risk (CM@Risk). The comparison is interesting because these two delivery models also allow fast-track and design-construction integration. However, we did not see any studies about this reported in the literature. The interviewees' answers were very promising for P3s. In terms of the design-construction integration, one responded:

> *CM at risk would generally suggest a "best practice" solution in design and construction, but P3s require the team to rise up to a higher level to satisfy a client's requirements. Moreover, in P3s, innovation arises at all levels throughout the whole process across various disciplines.*

Another interviewee for another project shared a similar opinion:

> *Compared to the DB model, the P3s have a long-term goal and the maintenance team is involved in the whole process of the project, which increases the flexibility of design and construction.*

Further, another interviewee from a consulting company said that although both DB/CM@Risk and P3s allow the construction expertise to be incorporated into design, the decision makers of the two delivery systems are different. There is no doubt that the project company is less risk averse than the public client.

4 Conclusions and Recommendations

As Canadian P3s move to the third stage where the industry seeks continuous improvement for a more robust project pipeline, having a better understanding of the effects of P3s on engineering innovations will enhance the ability of public procurers to maximize the efficiency of the nation's limited resources in the delivery of assets and services. Previous theoretical work on construction innovation and project delivery systems in general provided limited insights because disentangling the effect of a project delivery model on project performance is indeed a very difficult task. Empirical studies exist, but they were largely based on practices from Europe and Australia. Those findings are not necessarily applicable to Canadian P3s because many of the shortcomings of the British and Australian models have been addressed in the Canadian model.

In this study, an innovation refers to an alternative design, material, product, process, or method that proponents use either to maintain the competitive advantage in order to win the job during the proposal stage or to meet a certain particular job challenge during the implementation stage. The alternative solutions may be new ideas, but they can also be existing ideas that have not yet been routinely used in different projects. Interviewees involved in the study agreed that this is a fair definition.

Our empirical study based on interviews concluded that the Canadian P3 model does indeed provide both public and private partners with unique innovation opportunities that traditional delivery models cannot support. The major innovation opportunities result from integration of design, construction, and operations and maintenance. Traditional DBB divides these services to separate providers and thus foregoes the integration opportunities. Although other traditional models such as DB and CM@Risk also allow integration of design and construction expertise, the inherent risk aversion of the public client in those models often impedes innovation. In contrast, the risk allocation mechanism in P3s really incentivizes the private sector to innovate in both proposal and implementation stages.

The major motivations for innovation come from the pressures of bidding competition and risk allocation mechanisms. During the proposal stage, the major drivers for innovation include cost reduction, specification compliance, and performance enhancements. Here, cost reduction is defined as cost saving in the lifecycle sense, or simply the reduction in the net present value of the total lifecycle cost. In this stage, public clients play an important leading role particularly by developing flexible performance-based output specifications and by setting less cost-focusing proposal evaluation criteria. To develop a competitive proposal, all parties of the project company collaborate closely for a creative and integrative solution. During the implementation stage, the design and construction teams of the preferred proponent continue to work together to address challenges arising along the way. Design and construction innovation have been the private sector's major tool for mitigating the risks that have been transferred to them.

As a result, a great variety of design, engineering, and construction innovations have been adopted in Canadian P3s. While about 60% of the innovations identified from the interviews belong to incremental innovations, modular, architectural and system innovations are also observed. Visible differences among different infrastructure sectors exist in the nature and timing of innovations. In building P3s, innovations have often occurred in the RFP stage. Design innovations have been focused on areas related to adaption (both technological and demand) and sustainability (such as architecture footprint, energy performance, water consumption, LEED certification, the use of green materials, and solid-waste reduction). Construction-related innovations include construction resequencing and modular construction. In transportation and transit P3s, many innovations were brought up after financial closing by the project company internally to meet the challenges during the construction stage. This is a good indication that P3s have successfully transferred the construction risk to the private sector. Geotechnical risks, traffic management, and durability are the most frequent areas of innovation in transportation P3s.

The impacts of innovation vary across a wide range. Although the quantification of these impacts is beyond the scope of this study, interview participants from transportation and transit P3 projects reported that about 20 to 30 percent cost benefit has been observed, partly attributed to innovation and efficacy in the P3 delivery model.

It is also worth noting that many more innovative solutions were proposed than were accepted in the P3 projects that were interviewed about in the study. Many interviewees indicated that there is room for further enhancement of the delivery model to adopt more innovations in future projects. Among many they have made, the most frequently recommended suggestions are the following:

First, it is recommended that public clients continue to move away from the compliance culture and refocus their resources on addressing strategic issues such as needs, functionalities, performance, and levels of services by using systems engineering approaches. By so doing, public clients will develop a less prescriptive, truly output-focused project specification.

Second, P3s require strong teamwork. For this reason private partners, particularly architects, engineers, construction managers, and facility managers, are strongly recommended to work together more closely to fully embrace the lifecycle engineering opportunities. Many lifecycle issues such as performance deterioration, functional obsolescence, time-dependent reliability, maintainability, and inspectability need to be more properly addressed. High-impact innovations will only happen when the entire P3 market has built up the lifecycle capacity to its fullest strength.

Third, innovation will be further enhanced if the overall construction industry fosters an innovation culture. Collaborations with universities and applied research centres are expected to improve the opportunities for radical innovations in action. In this regard, both federal and provincial governments need to take action to enhance R&D investments in the infrastructure sector. Given the current state of aging infrastructures and the demand for renewed investments, this need could not be more urgent.

Finally, although beyond the scope of the study, quantification of efficiency gained from innovation is a large gap that needs to be filled. Due to commercial sensitivity, it is extremely difficult to obtain empirical efficiency data directly. Some creative ideas would be necessary as regard to how we distinguish and gauge separately the efficiencies gained from innovation, competition, risk allocation, and so on. Nevertheless, gauging the efficiency gain would provide insights into where and how the real opportunities for innovation are. In addition, innovation in financing arrangement has been recognized to be another major benefit that P3s provide beyond the traditional delivery approaches. Financing innovation is clearly another subject of future study.

To conclude, innovations are currently being realized and creating value for money in Canadian P3s. Both the private and public sectors have demonstrated a strong learning attitude toward continuous improvement of the delivery model.

Appendix A - The Selected P3 Projects

The selected P3 projects are listed in **Table 9.** The selected projects serve a good representative sample of the Canadian P3 projects. It includes 1 federal project, 3 municipal projects, and 15 provincial projects. Major infrastructure companies (e.g., Plenary Group and Fengate) and general contractors (e.g., SNC Lavalin, PCL, EllisDon, AECOM, AECON) are included in the list. The list has also a very good time span. It includes the very first P3 project in Canada (Confederation Bridge) and in Ontario (Highway 407 ETR). It also includes a few ongoing or recently completed P3 projects (e.g., Confederation Line or Ottawa LRT and Pan Am Athlete Village). The projects are located in four provinces (BC, AB, MB, ON). However, due to time constraint, the interview program was not able to cover all of the identified projects. Interviewees have discussed 15 of the 19 projects. The 15 projects are marked with asterisk.

Table 9: Details of the selected P3 projects

Project Name	Sector	Location	Delivery Modes	Project Status	Private Partner	Construction Timeline
Durham Consolidated Courthouse (*)	Courthouse	Oshawa	DBFM	Operational	Access Justice Durham	2007/03/01-2009/11/24
OPP Modernization Project (*)	Corrections	16 communities across Ontario	DBFM	Operational	Shield Infrastructure Partnership	2010/09/14-2012/11/23
Toronto South Detention Centre (*)	Corrections	Toronto	DBFM	Operational	Integrated Team Solutions	2009/10/26-2012/09/28
Bridgepoint Health (*)	Hospitals	Toronto	DBFM	Operational	Plenary Health	2009/08/11-2013/03/01
Highway 407 East Phase 1 (*)	Roads & Bridge	Greater Toronto Area	DBFM	Under Construction	407 East Development Group	2012/05/18-
Highway 407 ETR	Roads & Bridge	Greater Toronto Area	DBFMO	Operational	407 ETR Concession Company Ltd.	1987-1999
Ottawa LRT Project (Confederation Line) (*)	Public Transit	Ottawa	DBFM	Under Construction	Rideau Transit Group	2013/04-
The Rt. Hon. Herb Gray Parkway (*)	Roads & Bridge	Windsor-Essex region	DBFM	Under Construction	Windsor Essex Mobility Group	2010/12/15-

Project Name	Sector	Location	Delivery Modes	Project Status	Private Partner	Construction Timeline
Humber River Regional Hospital	Hospitals	Toronto	DBFM	Construction Complete	Plenary Health Care Partnerships	2011/09/23-2015/06/03
Niagara Health System (*)	Hospitals	St. Catharines	DBFM	Operational	Plenary Health Niagara	2009/03/27 2012/11-26
Women's College Hospital (*)	Hospitals	Toronto	DBFM	Under Construction	Women's College Partnership	2010/07/13-
Pan Am Athletes' Village	Recreation& Culture	Toronto Pan Am Secretariat (Ministry of culture)	DBF	Construction Complete	Dundee Kilmer Developments Ltd.	2011/12/14-2015/01/28
Brampton Civic Hospital	Hospitals	Brampton	DBFM	Operational	The Healthcare Infrastructure Company of Canada	2004-2007/06/30
Disraeli Bridges (*)	Roads & Bridge	Winnipeg	DBFM	Operational	Plenary Roads Winnipeg	2010/03/30-2012/10/19
Anthony Henday Drive Southeast (*)	Roads & Bridge	Edmonton	DBFM	Operational	Access Roads Edmonton Ltd.	mid 2004-2012/10/19
William R. Bennett Bridge	Roads & Bridge	Okanagan Lake, BC	DBFMO	Operational	SNC-Lavalin	July 2005-2008/03/31
Canada Line (*)	Public Transit	Metro Vancouver Area	DBFMO	Operational	InTransitBC Limited Partnership	2005/10-2009/08
Sea-to-Sky Highway Improvement Project (*)	Roads & Bridge	West Vancouver to Whistler	DBFMO	Operational	S2S Transportation Group	2005/08- Fall 2009
Confederation Bridge	Roads & Bridge	Borden-Carleton, Jourimain Island	DBFMO	Operational	Strait Crossing Development Inc.	1993/10/07-1997/05

Appendix B - The Interview Questions

The objective of the interviews is to understand what the notion of innovation is perceived by the industry, what and where innovative solutions have been used, and to identify the factors that led to the innovation being implemented. For this purpose, a series of interview questions were designed based on the major findings from the literature review on engineering innovation. For the ease of later analyses, the questions for both the private and public sectors have been mirrored as much as possible. The questions have been reviewed by the project client, PPP Canada.

The study focuses on innovation in design and construction. Funding and financing innovations are beyond scope of the study.

B.1 Questions for Project Proponents

1. (*Definition of innovation*) The definition of innovation is sometimes arguable. For example, some people differentiate between good design and innovative design. Some people argue that standardization of construction method and component modularization should be considered as innovation, but other people think those are small improvement. How do you define innovation?
2. (*Innovation and impacts*) What innovations (e.g., new technologies, new design concepts, new systems, and new construction methods) were used in the P3 project? What were the major impacts of those innovations on the project performance (e.g., cost, schedule, risk, ease of maintenance, public acceptance, quality, and level of service).
3. (*Innovation and motivation*) What were the major motivations for you to propose these innovations (e.g., client requirements, cost saving, schedule expediting, ease of maintenance, sustainability consideration, performance excellence, competitive advantage)?
4. (*Definition of innovation*) Were there any innovative design or technologies that you have used in a previous P3 or non-P3 project and re-applied to this P3 project? How did the clients perceive the innovativeness of the design or technologies in the P3 project?
5. (*Evaluation of innovation*) Were there any innovations proposed and not accepted by the clients? Why were some innovations adopted and others rejected?
6. (*Evaluation of innovation*) Some innovations may involve benefits or disbenefits that are not measurable or hard to measure. In this case, how did your client evaluate the proposal?
7. (*Implementation of innovations*) At what project stage were those innovations introduced? Were there any enhancements of the innovations made in later project stages? What were they? How were these enhancements materialized?

8. (*Implementation of innovations*) Were there any innovations adopted in design stage or construction planning stage and then aborted at a later stage of the project? Why were they aborted?
9. (*Innovation environment: performance-based specifications*) Many people say that innovation comes from flexible technical specifications and yet a firm performance target. How do you evaluate the flexibility of the performance specifications?
10. (*Innovation environment: intellectual properties*) There are concerns of intellectual properties in literature that the public procurer may want to apply the same innovation in one P3 project to another project, which might be built by other contractors. Is there any policy in the procurement system to protect your intellectual properties of the innovations?
11. (*Innovation environment: risk management*) Innovation and risk go hand in hand. How do you manage the risks from the new design/materials/construction methods/systems? How effective was your risk management? What key lessons did you learn?
12. (*Innovation environment: open question*) Based on your experience, how do you think the current P3 procurement process in encouraging/discouraging innovation from the private sector? What can the public procurer do to improve the process?

B.2 Questions for Public Procurers

1. (*Definition of innovation*) The definition of innovation is sometimes arguable. For example, some people differentiate between good design and innovative design. Some people argue that standardization of construction method and component modularization should be considered as innovation, but other people think those are small improvement. How do you define innovation?
2. (*Innovation and impacts*) What innovations (e.g., new technologies, new design concepts, new systems, and new construction methods) were used in the PPP project? Please also explain the major impacts on project performance (e.g., cost, schedule, risk, ease of maintenance, public acceptance, quality, and level of service).
3. (*Innovation and motivation*) Was innovation a required submittal in proposal? What were the motivations for requiring submitting innovative proposal?
4. (*Definition of innovation*) Were there any innovative design or technologies that have been used in some previous P3 or non-P3 projects?
5. (*Evaluation of innovation*) Were there any innovations proposed by the private sector and not accepted by you? Why were some innovations adopted and others rejected?
6. (*Evaluation of innovation*) Some innovations may involve benefits or disbenefits that are not measurable or hard to measure. In this case, how did you evaluate the proposal?
7. (*Implementation of innovations*) At what project stage were those innovations introduced? Were there any enhancements of the innovations made in later project stages? What were they? How were these enhancements materialized?

8. (*Implementation of innovations*) Were there any innovations adopted in design stage or construction planning stage and then aborted at a later stage of the project? Why were they aborted?
9. (*Innovation environment: performance-based specifications*) Many people say that innovation comes from flexible technical specifications while maintaining a firm performance target. What were the major challenges in developing outcome/performance-based specifications?
10. (*Innovation environment: intellectual properties*) There are concerns of intellectual properties in literature that the public procurer may want to apply the same innovation in one P3 project to another project, which might be built by other contractors. Is there any policy in the current procurement process to protect the benefits or intellectual properties of innovators? For example, did you include any mechanisms as part of your RFP to allow you (the procurer) to adopt some of the innovative ideas put forward by the unsuccessful bidders?
11. (*Innovation environment: risk management*) Innovation and risk go hand in hand. How do you manage the risks from the new design/materials/construction methods/systems? How effective was your risk management? What key lessons did you learn?
12. (*Innovation environment: open question*) Based on your experience, how do you think the current P3 procurement process in encouraging/discouraging innovation from the private sector? What can the public procurer do to improve the process?

B.3 Questions for Project Clients

1. (*Expectation*) As an end user, what kind of innovation did you expect the project would include? Were they included in the completed project?
2. (*Consultation and Involvement*) What role have you played in defining your need and performance expectation in project definition stage and proposal evaluation stage? Were your views and opinions solicited/welcomed? Were some of your suggestions adopted / rejected?
3. (*Perception*) Are you aware of any innovations that have been used in this project? What are they? Do you agree that those innovations are innovative indeed?
4. (*Innovations and Impacts*) Have you noticed any impacts of the innovations on the project performance and/or the quality of the facility?
5. (*Innovation environment: open question*) Based on your experience, how do you think the current P3 procurement process in encouraging/discouraging innovation from the private sector? What lesson have you learned from the previous P3 projects?

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