A Framework for Evaluating the Impact of Construction Research and Development on University, Construction Industry, and Government

by

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Abstract

Research and development (R&D) partnerships among universities, industries, and government agencies involve investigative activities that may result in new discoveries and innovations. While R&D partnerships are critical for the technological advancement of the construction industry, they require substantial financial support. Although demonstrating the value of these partnerships is essential for encouraging investment, the construction research domain lacks a formal evaluation framework. To address this problem, this study introduces a logic model approach that uses an input-output-outcome-based methodology for evaluating construction R&D partnerships, where inputs represent resources, outputs represent activities, and outcomes represent intended results.

The developed framework was tested using a pilot study that focused on the evaluation of the university's role within a collaborative construction research program under the Natural Sciences and Engineering Research Council of Canada (NSERC) Industrial Research Chair (IRC) program, namely the NSERC IRC in Strategic Construction Modeling and Delivery (SCMD). Using canonical and Spearman's correlation analysis, this study showed the investments and activities for the university research team that lead to desired outcomes of the R&D partnership. The contributions of this study include: (1) introducing the concept of the logic model, which has been used for program evaluation in a range of contexts, to the construction research domain; (2) presenting a framework with detailed evaluation criteria and measurement metrics that will assist research teams and funding agencies in evaluating and improving current R&D partnerships; (3) presenting a statistical approach that will help in identifying relationships between the components of R&D partnership, so that inputs and outputs can be improved to achieve the

desired outcomes of each collaborating party; and (4) presenting a validated logic model to evaluate the university's role within the NSERC IRC in SCMD.

Preface

This thesis is an original work by Ahmed Osama Elsayed Daoud. The research project, of which this dissertation is based on, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "An Evaluation Framework for Assessing the Impact of Construction Research and Development (R&D) on the University, Construction Industry, and Government", Study ID: Pro00059440, approved on April 18, 2016.

Parts of this thesis's chapters have been submitted for publication as Daoud, A. O., Tsehayae, A. A., and Fayek, A. Robinson. (2016). "Guided Evaluation of the Construction R&D Impact on University, Construction Industry, and Government." *Can. J. Civil Eng.,* in review, submitted August 10, 2016. I was responsible for the major parts of the data collection, and together with Tsehayae A.A. worked on the analysis and the composition of the manuscript. A. Robinson Fayek was the supervisory author and was involved with concept formation and composition and editing of the manuscript.

Dedication

First and foremost, I would like to thank God who supported me in facing all the challenges in this research and who gifted me wonderful people to lighten up my journey in this life.

This thesis is dedicated with love and sincerity to:

My lovely mother, whom without I would not have reached any achievement in my life, who never stops supporting me in countless ways,

My great father, the role model, who taught me how to fight in this life for my dream,

My beloved wife, who believed in me and in my dream and loved me for who I am,

My dearest family, the source of giving and love that never forgets me in its prayers,

My faithful friends, who are supporting and encouraging me, who stand beside me in my best and worst of times,

Everyone who I met throughout my life journey, who touched my heart and inspired me by their well manners,

My expected child, who is coming to bring all the happiness in this world to my heart, in which the news of his arrival to this world gave me ambition, enthusiasm, happiness, and energy to do my best in this research.

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CHAPTER 1 INTRODUCTION[1]

1.1 Background

Research and development (R&D) is defined by the Organization of Economic Co-operation and Development (OECD) (2002) as “a creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications”. R&D activity is “the sum of actions deliberately undertaken by R&D performers in order to generate new knowledge” (OECD 2015). Accordingly, each R&D project is made up of a set of different R&D activities which has its own objectives and intended outcomes (OECD 2015). R&D projects can be classified as basic research projects, applied research projects, and experimental development projects. First, basic research project is “experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view” (OECD 2015). Second, applied research project is “original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective” (OECD 2015). Third, experimental development project is “systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes” (OECD 2015).

Some R&D projects are carried out through R&D partnerships. This study focuses on R&D partnerships; each R&D partnership consists of different R&D projects on which different parties collaborate together to reach their expected outcomes of the collaboration. R&D partnership programs between universities and industries (e.g., companies, associations, labour groups), which help to bridge the gap between knowledge and practice, are becoming prevalent. Lee and Win (2004) described these collaborative relationships as interactions between a higher educational system and an industrializing economy. Universities, industry groups, and

[1]Parts of this chapter have been published in the Proceedings, ASCE Construction Research Congress 2016, San Juan, Puerto Rico, May 31-June 2: 78-87, and submitted for publication in Canadian Journal of Civil Engineering, 29 manuscript pages, submitted August 10, 2016.

government agencies are considered to be the main drivers of R&D partnership programs. Hagedoorn et al. (2000) defined R&D partnerships as "cooperative arrangements engaging universities, industries, and government agencies and laboratories in various combinations to pool resources in pursuit of a shared R&D objective." Universities and industry groups are commonly linked by a strong relationship through R&D projects (Lee and Win 2004), and there are many advantages of collaboration for both parties. For example, R&D partnerships afford industry groups opportunities to gain technical knowledge and expertise; train their employees; recruit from a pool of highly qualified personnel, such as graduate students; and improve their practices through the development and implementation of new technologies (Lee and Win 2004). In turn, universities benefit from opportunities to apply theoretical research to real-life problems, commercialize their work, and gain access to new funding and data sources, expert knowledge, and protected markets (Lee and Win 2004).

Collaboration between universities and industries has increased significantly over the past 20 years (Hanel and St-Pierre 2006). In fact, Canada is ranked first among G7 countries in regards to support for university research by the private sector (Hanel and St-Pierre 2006; Innovation, Science and Economic Development Canada (ISED) 2014). Firms that collaborate with universities on R&D projects receive many economic benefits: 1) maintaining a high competitive position among their peers; 2) maintaining a profit margin; 3) increasing their share in international and domestic markets; and 4) increasing their profitability and adaptability. Hanel and St-Pierre (2006) conclude that most leading innovations are developed by firms that are engaged in partnerships with universities. Construction R&D involves collaboration amongst three parties: universities, industry or private sector groups, and government or public sector agencies. These groups are the main source of funding for construction R&D in Canada (Fayek et al. 2014). The government of Canada plays a significant role in funding R&D programs in the construction domain through different organizations such as National Research Council (NRC), Canada Foundation for Innovation (CFI), and Natural Sciences and Engineering Research Council of Canada (NSERC). Among the three, NSERC makes critical contributions towards R&D enhancement in Canada (NSERC 2011). The main goal of NSERC is to "provide Canadians with economic and social benefits arising from the provision of a highly skilled workforce, knowledge transfer of Canadian discoveries in the natural sciences and engineering from universities and colleges to other sectors, and informed access to research results from around the world" (Goss Gilroy (GG) 2006).

The Industrial Research Chair (IRC) program is one of several collaborative university-industry-government R&D programs facilitated by NSERC (GG 2006). The IRC has three main objectives: 1) helping universities to strengthen their existing areas of research expertise in order to achieve breakthroughs in science and engineering that are applicable to industry; 2) supporting the expansion of new research areas that have not yet been developed in Canadian universities and that will address significant industrial needs, and 3) providing graduate students and postdoctoral fellows with enhanced training by involving them in research activities relevant to industrial problems and in interactions with industrial partners (GG 2006; NSERC 2014). An example of a successful IRC (i.e., research partnership) within the IRC program has been demonstrated by AbouRizk (2010), who investigated the role of his long-term collaboration spanning the past 15 years with NSERC and a number of industry partners, which has been dedicated to the development of simulation modeling tools and techniques for use by the construction industry. AbouRizk (2010) noted that in addition to providing financial support for his research, this on-going collaboration has allowed him to cultivate a nuanced understanding of industry needs, and has afforded him opportunities to apply his work on simulation modeling in a range of real-life contexts such as tunneling projects, expansion of light-rail transit, water treatment plants, tower crane modeling, and module yard scheduling.

Despite the benefits to be gained through these collaborations, industrial support for R&D in Canada has been noticeably decreasing over the past few years (Statistics Canada 2015). Statistics Canada reported that in 2015, Canadian businesses anticipated investments of approximately $15.5 billion for R&D activities, which is 2.6% less than the $15.9 billion budgeted in 2014 and 3.6% less than the $16.0 billion budgeted in 2013. These findings also show that financial support for construction R&D has decreased from $158 million in 2011 to $79 million in 2015 (Statistics Canada 2015). R&D has not been a central focus for many Canadian firms, and this has negatively affected university-industry collaboration (Council of Canadian Academies (CCA) 2013). The OECD (2009) identified reduced cash flow resulting from the world economic crisis as the main reason for the declining investments in R&D projects.

During times of economic turbulence, markets, investors, and banks tend to prefer short-term, low-risk R&D projects with more direct and immediately accessible outcomes over long-term R&D projects that may pose more substantial risks, but offer the possibility of new discoveries and innovations.

In addition, industry groups do not always get what they expect from R&D collaborations (Hanel and St-Pierre 2006). For example, Lee (2000) surveyed 280 companies and 40 universities regarding their involvement in R&D partnerships in the US. The majority of the companies involved in the study responded that they had received no benefits from their participation in R&D collaborations in regards to the recruitment of highly qualified personnel (e.g., students) and had seen no improvement in the quality of their products (Lee 2000). However, the overwhelming majority of respondents from both companies and universities stated that they were interested in enhancing or maintaining their present level of collaboration. To enhance the performance of industrial R&D partnerships (IR&D) in Canada, the demand for IR&D must be increased, especially across large Canadian firms, and new investments need to be attracted (CCA 2013). The CCA (2013) recommended that Canadian firms increase their investments in R&D projects to ensure their future growth, and maintain their competitive advantage and profitability. In order to foster effective collaborative relationships between universities and industry groups, the mutual value of R&D partnership programs must be demonstrated. There are a number of tools that can be used to develop, implement, and evaluate R&D partnership programs, though the "logic model" stands out as one of the most effective options.

The W.K. Kellogg Foundation (WKKF) (2004) defined the logic model as "a systematic and visual way to present and share your understanding of the relationships among the resources you have to operate your program, the activities you plan, and the changes or results you hope to achieve". Logic models schematically express relationships between what is invested in a program, what is done through the program, and what has been achieved as a result of this program (Dwyer and Makin 1997). More specifically, logic models consist of inputs, outputs, and outcomes, which are connected together by causal relationships (Millar et al. 2001). Taylor-Powell and Henert (2008) offered the following definitions of inputs, outputs, and outcomes:

inputs are the resources invested in the program (e.g., funds, people, time, skills, and experience); outputs are the completed activities carried out through the program (e.g., conferences, workshops, and publications) and people who are reached and impacted by the carried out activities (e.g., stakeholders, decision makers, clients, organizations); and outcomes are the intended results of the activities and the changes expected by the program participants. Outcomes can be further classified as either short-term, medium-term, or long-term outcomes. Short-term outcomes result directly from outputs and include changes in knowledge, skills, attitudes, motivation, and awareness. Medium-term outcomes result after the fulfillment of short-term outcomes and include changes in behaviors, practices, decisions, actions, strategies, and policies. Long-term outcomes, also known as impact, result after the fulfillment of the medium-term outcomes and include changes in social, economic, political, scientific, and environmental conditions. Once the components of the logic model have been identified, an "evaluation plan" can be developed to evaluate the program's components. Over the past two decades, logic models have been used extensively by evaluators and program managers to plan and implement R&D programs, and assess the efficiency and expected outcomes of these programs (Dwyer and Makin 1997; McCawley 2001). In the literature, there many examples discussing the application logic models in a number of different contexts as well as their benefits; however, logic models have not yet been applied in the construction research domain.

1.2 Problem Statement

The construction domain lacks a framework for evaluating the outcomes and impact of R&D partnerships amongst universities, industry groups, and government agencies. As discussed in the background section, logic models have been widely used in developing and evaluating programs in a range of different contexts, such as health research domain; however, logic models have not yet been applied in the construction research domain. Before a framework for evaluating construction R&D partnerships can be developed, there are four major problems that must be addressed.

First, there is a lack of clear definitions regarding the components of construction R&D partnerships (i.e., inputs, outputs, and outcomes/impact). Moreover, there is no clear separation between the meanings of these components; for example inputs include the resources invested by participants in program activities, yet outputs also encompass the activities carried out through the program, and outcomes/impact are the expected results of the program. The second problem is related to the absence of an approach for representing the qualitative relationships between the different components of construction R&D partnership programs, such as the NSERC IRC program. To reiterate, while logic models have been used to visualize interrelationship between the components of R&D partnerships in other research domains, they have not yet been applied in the context of construction research domain. Third, there is an absence of a detailed measurement scheme, including evaluation criteria, metrics, and scales, that would permit the assessment of the different components of R&D partnership programs (i.e., inputs, outputs, and outcomes). Finally, the fourth problem is related to the lack of a study evaluating R&D partnerships in the construction research domain. In addition, there is a need for a defined methodology or framework to evaluate the different components of construction R&D partnerships in order to determine which inputs highly relate to outputs, and which outputs highly relate to outcomes. Collaborating parties may not be able to easily quantify or assess the outcomes of the R&D partnership, let alone be able to determine relationship between partnership components.

1.3 Research Objectives

The main goal of this thesis is to provide the construction research domain with an evaluation framework to assess the outcomes and impact of R&D partnerships based on the role of each collaborating party (i.e., university, industry, and government), so that their respective inputs and the outputs can be improved to better deliver the outcomes each expects. This evaluation framework defines and evaluates the outcomes for each party by assessing qualitative relationships among the different components of construction R&D partnerships. The detailed objectives of this research are as follows:

1. To define and represent the different components (i.e., inputs, outputs, and outcomes) of construction R&D partnerships in a way that establishes clear separation between the invested resources, activities, and intended results of the partnership.

2. To provide the construction domain with a logic-model-based approach to visualize interrelationships between the components of R&D partnerships (i.e., inputs, outputs, and outcomes) and contribute to a better understanding of the connections (i.e., qualitative relationships) between the invested resources, activities, and intended results.

3. To define and state the major evaluation criteria, corresponding metrics (i.e., indicators), and measurement scales for inputs, outputs, and outcomes of the partnership, which can be used in the evaluation of R&D partnerships (in general), and in the evaluation of different IRCs within the NSERC IRC program.

4. To establish correlations among the different components of R&D partnerships that are relevant to role of the university. Through statistical evaluation of data collected on the defined criteria, the correlations between the different criteria will be established to determine which inputs highly relate to the outputs, and which outputs highly relate to the outcomes.

1.4 Expected Contributions

This thesis is intended to produce a wide range of contributions that will positively impact the three main collaborating parties in Canadian construction R&D partnerships (i.e., universities, industry groups, and government agencies). Some of these contributions are more relevant to researchers (e.g., university) and are thus classified as academic contributions, while other contributions are more relevant to the construction industry or the government and are classified as industrial or governmental contributions.

1.4.1 Academic Contributions

The expected academic contributions of this research are as follows:

- Defining and representing the different components of R&D partnerships that are relevant to the role of the university.

- Compiling a list of evaluation criteria and assigning metrics and scales to them in order to assess the university's role in R&D partnerships. Evaluation criteria, metrics, and scales will be selected based on a literature review of logic models and R&D partnerships.

- Introducing both a generic logic model that can be applied to visualize and evaluate the university's role in R&D partnerships (in general), as well as a generic submodel that can be applied to visualize and evaluate the university's role within different IRCs.

- Proposing a methodology for the development of an integrated logic model and evaluation plan that will help in identifying and assessing qualitative relationships among the different components of R&D partnerships.

- Demonstrating the importance of evaluating different IRCs within the NSERC IRC program that are conducting research related to the construction domain. The proposed evaluation framework will be used to assess the university's role within the NSERC IRC in Strategic Construction Modeling and Delivery (SCMD).

- Identifying crucial areas of investment for the university research team for the NSERC IRC in SCMD order to achieve better future outcomes.

1.4.2 Industrial Contributions

The expected industrial contributions of this research are as follows:

- Introducing clear definitions of the different components of R&D partnerships that are relevant to the role of industry groups.

- Presenting a list of evaluation criteria, metrics, and scales to assess the role of industry groups in R&D partnerships. Evaluation criteria, metrics, and scales will be selected based on a literature review of logic models and R&D partnerships.

- Presenting a generic logic model for visualizing and evaluating the role of industry groups in R&D partnerships (in general), as well as a generic submodel for visualizing and evaluating the role of industrial partners within different IRCs. These models will help industry groups to better understand the link between the components (i.e., inputs, outputs, and outcomes) of R&D partnerships.

1.4.3 Governmental Contributions

The expected governmental contributions of this research are as follows:

- Introducing clear definitions of the different components of R&D partnerships that are relevant to the role of government agencies.

- Presenting a list of evaluation criteria, metrics, and scales that can be used to assess the government's role in R&D partnerships. Evaluation criteria, metrics, and scales will be selected based on a literature review of logic models and R&D partnerships.

- Presenting a generic logic model for visualizing and evaluating the role of government agencies in R&D partnerships (in general), as well as a generic submodel for visualizing and evaluating the role of NSERC within different IRCs. This can help government agencies to better understand the link between the components (i.e., inputs, outputs, and outcomes) of R&D partnerships.

1.5 Research Methodology

The evaluation framework presented in this thesis will be developed over four main stages:

(1) Literature review of R&D partnerships and logic models;

(2) Compilation of evaluation criteria, corresponding metrics, and scales for the different components (i.e., inputs, outputs, and outcomes) of R&D partnerships (in general), and for different IRCs within the NSERC IRC program;

(3) Development of a generic logic model for R&D partnerships (in general), as well as generic submodel for different IRCs within the NSERC IRC program. These models will help to represent the qualitative relationships between the different components of R&D partnerships;

(4) Development of a methodology to evaluate R&D partnerships and to establish correlations among the partnership components. The proposed evaluation framework (i.e., the verified generic submodel and evaluation plan) will be applied to a pilot study for a construction research program specifically the NSERC IRC in SCMD.

The **first stage** includes a literature review of R&D programs in general; the status of R&D programs in Canada and other OECD countries, such as the United States and Australia; and forms of knowledge transfer between universities and industries. In addition, advantages of R&D partnerships will be explored, as well as barriers to effective collaborative relationship between universities and industry groups and strategies for mitigating these barriers. Finally, applications for logic models in program evaluation will be investigated as well as different types and structures of logic models, their advantages, and process for developing logic models. The **second stage** involves the compilation of different evaluation criteria and their corresponding metrics and measurement scales. These criteria represent the different components of R&D partnerships, while the metrics define the data that will be collected for the purpose of the evaluation (University of Wisconsin-Extension (UWEX) 2003). Numerical scales will be used to measure quantitative metrics (Rea and Parker 1997) and Likert scales will be used to measure qualitative metrics (Rea and parker 1997; Vagias 2006).

The **third stage** involves the development of the generic logic model and generic submodel, which will represent the qualitative relationships between the different components of R&D partnerships (in general), and for the different IRCs within the NSERC IRC program, respectively. These logic models can be classified as outcome-approach models (WKKF 2004). The generic logic model is developed through tabulating the criteria that represent the components of R&D partnerships that are relevant to the role of each of the three collaborating parties, in which each model component (i.e., inputs, outputs, and outcomes) consists of a number of different criteria. In contrast, the generic submodel is developed by refining and tailoring the criteria established in the generic logic model for each party to suit the context of their participation in the NSERC IRC program. The **fourth stage** entails the development of a methodology for evaluating R&D partnerships and for establishing correlation among the components of the partnership. This process is accomplished by applying the proposed evaluation framework (i.e., validated generic submodel and evaluation plan) to a pilot study, which focuses on a construction research program specifically the NSERC IRC in SCMD, to evaluate the university's role within the NSERC IRC in SCMD. The final stage consists of the following five steps:

a) Designing questionnaires to collect data for each metric.

b) Verifying the components of the proposed submodel and the developed questionnaires. This step is important in refining the criteria stated in the generic submodel before it is applied to the pilot study (i.e., the NSERC IRC in SCMD). In addition, these efforts help to ensure that the content of the questionnaires is contextually relevant and unambiguous to respondents. Verification will be carried out to solicit input from experts and professionals representing all parties in order to ensure that the logic model and questionnaires are well-developed.

c) Implementing the data collection methods (i.e., questionnaires) with university research team members for the NSERC IRC in SCMD in order to assess the inputs, outputs, and outcomes relevant to the university's role in the partnership.

d) Analysing the collected data to establish correlations among the components of the partnership and to evaluate the role of the university in the IRC. The data analysis will be carried out using statistical analysis methods such as canonical correlation analysis (CCA) and Spearman's correlation analysis (SCA).

e) Presenting a validated logic model to evaluate the role of the university in the NSERC IRC in SCMD.

1.6 Thesis Organization

Chapter 1 provides essential background regarding this thesis; a brief literature review examining the nature of R&D partnerships, especially involving Canadian participants, and a statement regarding the research problem. In addition, Chapter 1 investigates the expected contributions of this research and its methodology.

Chapter 2 offers a literature review of R&D partnerships between universities, industry groups, and government agencies, and explores examples from Canada and other OECD countries such as the United States and Australia. Chapter 2 also examines the forms of knowledge transfer facilitated by these partnerships, the advantages of involvement in R&D partnerships for universities and industry group, as well as the barriers to effective collaborations and the mechanisms that can be applied to mitigate these barriers. Finally, applications for logic models in program evaluation will be investigated as well as different types and structures of logic models, their advantages, and process for developing logic models.

Chapter 3 presents the compiled evaluation criteria representing the components of R&D partnerships, as well as the corresponding metrics and measurement scales. In addition, the proposed generic logic model for R&D partnerships (in general), and the proposed generic submodel for different IRCs within the NSERC IRC program are presented.

Chapter 4 covers the pilot study investigated in the thesis, which applied the developed evaluation framework to the role of the university within the NSERC IRC in SCMD, a specific

IRC partnership existing under the NSERC IRC program. In addition, Chapter 4 presents an analysis of responses from the questionnaires completed by the university research team for the IRC in SCMD using Statistical Package for Social Science (SPSS) software and different statistical analysis methods such as canonical correlation analysis (CCA) and Spearman's correlation analysis (SCA). In addition, this chapter presents a validated logic model in order to evaluate the university's role in the NSERC IRC in SCMD.

Chapter 5 describes the conclusions, contributions, and the limitations of this study, as well as recommendations for future research.

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CHAPTER 2 LITERATURE REVIEW OF R&D PARTNERSHIPS AND LOGIC MODELS[2]

2.1 Introduction

Universities and industry are linked by a strong relationship based on collaboration in research and development (R&D) projects (Lee and Win 2004). In addition, governments play an important role in maintaining R&D progress (Hampson et al. 2014). These partnerships include different forms of knowledge and technology transfer between universities and industry for a strong collaboration (Bekkers and Freitas 2008). However, these partnerships can be affected by some barriers that affect the development and performance of R&D programs (Bruneel et al. 2010). In addition, the industry is not focusing on R&D projects and it is not investing sufficient funds in them nowadays (Council of Canadian Academies (CCA) 2013; Statistic Canada 2015). Therefore, it is critically important to demonstrate the value of R&D partnerships to all the partners in order to; ensure a continued relationship and maintained collaboration, mitigate any barriers of the partnership, and enhance communication between partners. This can be achieved by evaluating the different components of the R&D partnership using an evaluation framework. Considering an efficient tool for evaluating and assessing R&D programs, "logic model" is one of the most effective tools to develop, implement, evaluate, and assess a program (Fielden et al. 2007).

This chapter presents a literature review of R&D partnerships, current status of R&D in Canada and in other countries such as United States of America and Australia, forms of R&D partnerships (i.e., knowledge and technology transfer) between universities and industry, and advantages of collaboration between universities and industry. In addition, it investigates barriers to universities and industry relationship, and the mechanisms of mitigating these barriers. This chapter also presents a literature review of logic models and their applications, types of logic models, and different structures of logic models. Also, it investigates the advantages of using

[2]Parts of this chapter have been published in the Proceedings, ASCE Construction Research Congress 2016, San Juan, Puerto Rico, May 31-June 2: 78-87, and submitted for publication in Canadian Journal of Civil Engineering, 29 manuscript pages, submitted August 10, 2016.

logic models, how to develop a logic model, and using logic models in evaluation and assessment.

2.2 Literature Review of R&D Partnerships

2.2.1 Nature of the Relationship between Universities and Industry and Current Status of R&D Partnerships

Universities (U), industry (I), and governments (G) are the main drivers of R&D innovative programs. Universities and industry are linked by a strong relationship through collaboration in research and development (R&D) projects (Lee and Win 2004). Lee and Win (2004) stated that the universities and industry collaboration is an interaction between higher educational system and industrializing economy. Governments also support R&D partnerships, and maintain a strong collaboration between universities and industry for the development of societies through innovative R&D results (Hampson et al. 2014). Hagedoorn et al. (2000) defined R&D partnership as "cooperative arrangements engaging universities, industries, and government agencies and laboratories in various combinations to pool resources in pursuit of a shared R&D objective." There are different reasons for initiating the R&D collaboration (Lee and Win 2004). Industry seeks innovative research carried out by university and the experience of qualified graduate students. On the other hand, a university seeks to cooperate with the industrial sector to address market needs, link theory with practice, and develop new technologies. Also, it seeks funds for its research when the governments start to reduce the funds allocated for R&D. Lee and Win (2004) claimed that universities and industry can start their collaboration through four ways: 1) firms search for university's research center which can help them in solving problems in hand, 2) firms may receive a collaboration proposal from universities to work together in R&D projects, 3) firms may make use of a third party, which can help firms in searching for qualified research centers in universities, and 4) firms may receive a collaboration proposal from a liaison third party to start a partnership in R&D projects with local R&D research centers and institutes.

The government of Canada is playing an important role in supporting construction R&D programs (Fayek et al. 2014). The support of the Canadian government to construction R&D

programs is much greater than that of the construction industry. The government of Canada supports R&D partnerships in the construction domain through different organizations such as; National Research Council (NRC), Canada Foundation for Innovation (CFI), and Natural Sciences and Engineering Research Council of Canada (NSERC). The NSERC is one of the largest Canadian sources of funding R&D partnerships. In 2012, the statistics showed that the intended investment of the construction industry in construction R&D projects was CAD101 million while the intended investment of the NSERC (i.e., government) in construction R&D projects was CAD347 million (Fayek et al. 2014). This means that the Canadian government's financial support, represented by the NSERC, to construction R&D projects is three times more than that of the industrial support.

The status of construction R&D investments in the United States of America is similar to that in Canada. The annual investments of the US in construction R&D are approximately USD2 billion, in which the major investments come from the federal agencies such as; National Science Foundation (NSF), Department of Energy (DOE), Environmental Protection Energy (EPA), Department of Transportation (DOT), and Department of Commerce (DOC) (Slaughter et al. 2014). The American Society of Civil Engineers (ASCE) Civil Engineering Research Foundation (CERF) conducted a survey across the US to investigate the funding of construction R&D programs (Slaughter et al. 2014). This survey included Federal agencies (i.e., governmental bodies), universities, industry, state and local government, and non-profit organizations. It was found that about two-thirds (i.e., 63 per cent) of construction R&D expenditures were invested by Federal agencies, 16 per cent were invested by industry, 12 per cent were invested by universities, and 9 per cent were invested by other organizations (Slaughter et al. 2014). This shows that the US government plays an important role in funding and supporting R&D projects, in which the US government's financial support to construction R&D is five times more than that of the US companies.

Contrary to the current status of the R&D investments in Canada and the United States of America, Australia has a different situation. Construction R&D projects encountered a great increase and a shift in the investments of the industry between 1992 and 2010 (Kraatz and Hampson 2014). Australian public institutions (i.e., universities) were investing three times more than the Australian private sector (i.e., construction industry) in construction R&D in the early 1990s (Kraatz and Hampson 2014). By 2008, the Australian private sector was found to be investing in construction R&D programs eight times more than universities (Kraatz and Hampson 2014). But unfortunately, the support of the Australian government to construction R&D programs has been declined. In the period between 1992 and 2008, it was found that the Australian government has decreased its investment in construction R&D projects from 2.2 per cent to 0.5 per cent of total governmental R&D expenditure (Kraatz and Hampson 2014). This shows that the support of Australian construction industry to construction R&D projects is much greater than Australian universities and government.

Universities are supplying the industry with new technologies and innovative ideas (Lee and Win 2004). The relationship between universities and industry is very strong in industrialized countries to enhance the technology exchange. New technologies are important for economy improvement and development of nations. Thus, universities play an important role by supplying the industry with new technology and qualified personnel (Lee and Win 2004). This collaboration between both parties has vastly increased over the past 20 years (Hanel and St-Pierre 2006). It is worth mentioning that the industry-university collaboration (IUC) in Canada is ranked as the first among G7 countries (Hanel and St-Pierre 2006). Canadian universities are ranked as the second largest funder of R&D projects after the industry (Hanel and St-Pierre 2006). However, the funding of universities to R&D projects has been decreased since 1971 (Hanel and St-Pierre 2006). As a result of that, universities start collaborations with the industry to help them in funding their researches. Statistics indicate that 5,081 research contracts were signed in Canada by universities and the industry between 1997 and 1998 with an average value of 57,000 dollars per research contract (Hanel and St-Pierre 2006). In other words, industry plays an important role in funding the university's research. In Canada, industry funding has been doubled since 1980. Industry used to share in university funding with 6.3% of the total funding of university research in 1980; however, industry started to share in university funding with 11.8% of the total funding of university research since 1997 (Hanel and St-Pierre 2006). Industrial support of university research in Canada is considered to be the first among the G7 countries (Hanel and St-Pierre 2006; Innovation, Science and Economic Development Canada (ISED) 2014).

Based on what has been discussed, it is clear that the relationship between universities and industry is a mutually beneficial relationship. Universities are involved in collaborations with industry for funding their research, enhancing their excellence, having a prestigious position and good reputation within universities by creating knowledge, and applying their theories in real life (Hanel and St-Pierre 2006). Industry is encouraged to collaborate with university in order to gain knowledge and expertise, develop and use innovative ideas, and apply new technologies. However, industry does not always get what they expect from this collaboration (Hanel and St-Pierre 2006). For example, Hanel and St-Pierre (2006) stated that they surveyed 91% of the companies and 94% of universities about their collaboration and they claimed that this collaboration should be enhanced or kept at its present status. In addition, Lee (2000) surveyed 280 companies and 40 universities about their collaboration for the purpose of assessing the R&D partnership. The majority of companies involved in R&D collaborations with university responded that they are receiving no benefits from the R&D collaborations regarding the recruitment of highly qualified students and also no improvement of product quality (Lee 2000). However, companies and universities involved in this survey claimed that this collaboration should be enhanced or kept at its present status. .

The CCA (2013) stated the following about the industrial R&D (IR&D) funding; "the Canadian business sector invests relatively little in IR&D compared to peers abroad, although some industries are highly IR&D intensive by international standards." The CCA (2013) found that the financial support of Industry to R&D in Canada is approximately half of what is in the U.S. and it is decreasing. The organization claimed that the reason of decreasing the financial support to R&D is that IR&D is not the main focus of many Canadian firms to enhance their competitiveness among their peers. The organization stated that Canada is suffering now from a relatively weak performance of the IR&D, in which the industry funding decreased and this negatively affected the collaboration between universities and industry. There are Canadian industries that are suffering a low IR&D strength, such as; construction, motor vehicles, chemicals, and food products. However, the organization stated that still there are several Canadian industries which show higher IR&D strength than those in all other G7 countries such as; communications equipment manufacturing, office and computing machinery manufacturing, coke and refined petroleum products manufacturing, and pulp and paper.

The industrial support to R&D in Canada has noticeably decreased over the past few years (Statistics Canada 2015). In order to support the conclusion of the CCA (2013) regarding the status of R&D in Canada, statistics were reviewed in the latest report prepared by Statistics Canada in 2015 about the funding of industrial R&D. Statistics Canada (2015) stated that the industry in Canada intends to support R&D with CAD15.5 billion, which is less than 2014's plan of CAD15.9 billion by 2.6%, and less than 2013's actual expenses of CAD16.0 billion by 3.6%. The most recent peak of IR&D financial support was in 2011 of a value equal to CAD16.9 billion (Statistics Canada 2015). These data were collected based on a survey prepared by the 2013 Research and Development in Canadian Industry (RDCI), in which the survey was sent to a sample of 1947 enterprises (Statistics Canada 2015). This survey was sent to the enterprises in September 2014 and it was closed in February 2015. The collected data showed the actual R&D expenses for 2013, the planned R&D expenses for 2014, and the R&D spending intentions for 2015. The results show how the financial support of IR&D has been declining over the years. The Organisation for Economic Co-operation and Development (OECD) stated that the main reason for the declined investments in R&D projects is the worldwide economic crisis (OECD 2009). R&D projects are mainly financed from cash flow which is decreasing as a result of the economic crisis. On the other hand, markets, investors, and banks tend not to take too much risk by investing in short-term, low-risk innovation R&D projects instead of long-term, high-risk innovation R&D project. This decline in R&D projects affected the collaboration between university and industry severely. Statistics Canada (2015) mentioned that most of the IR&D funding is spent on the engineering and technology research with a main focus on information and communication technology; however, the construction R&D is suffering from a decrease of Industrial support since 2011 (Statistics Canada 2015). The statistics show that the financial support for construction R&D has decreased from CAD158 million in 2011 to CAD79 million in 2015 (Statistics Canada 2015).

To enhance the performance of IR&D in Canada, the IR&D demand should be widened across Canadian large firms and new investments should be attracted (CCA 2013). The CCA (2013) recommended encouraging Canadian firms to spend more on R&D projects for the sake of their future survival, maintaining high competition among other firms in the market, success, and high profits. By doing that, the number of economically competitive firms will increase and their demand for more innovative ideas will increase. Consequently, the increasing demand for innovation will lead to increase in the IR&D support (CCA 2013).

2.2.2 Forms of Knowledge Transfer between Universities and Industry within R&D Projects

The existing literature showed different forms of knowledge and technology transfer between universities and industry in R&D projects. Hanel and St-Pierre (2006) stated that knowledge and innovative ideas are flowing between both parties as the flow of goods between different industries. Lee and Win (2004) described nine mechanisms for knowledge transfer between universities and industry. The first mechanism is collegial interchange, conference, and publication. This is a free and informal popular mechanism of exchanging knowledge within colleagues through publications and presentations at conferences. It is considered as the initiating step of linking universities with industry. The second mechanism is consultancy and technical services provision. It depends on hiring faculty members and researchers during the allowed time to work outside universities. They are hired for consultancy purpose, and providing information and technical services through a formal short term specific contract. The third mechanism is exchange program. In this mechanism, an exchange of experienced personnel from universities to industry and vice versa is carried out to transfer knowledge between them.

The fourth mechanism is joint venture of R&D. In this mechanism, research costs are shared based on a contractual agreement between universities and industry. Both parties start collaboration from R&D stage until commercialization. The fifth mechanism is cooperative R&D agreement. It is based on mutual benefit agreement, in which the university supplies this collaboration with qualified personnel, facilities, and other resources with or without being reimbursed for that. On the other side, the industry supplies this collaboration with funds, experienced personnel, services, and equipment to pave the way for universities to conduct their research. The sixth mechanism is licensing. This mechanism depends on transferring some rights in intellectual property to a third party, to let it use the intellectual property. To get this license, the industry must provide plans for commercializing the invention.

The seventh mechanism is contract research. Collaboration is undertaken through a formal contract between the industry and university's research center, in which the industry supply the relationship with funds and the university supply the relationship with innovative researchers to work on R&D projects within a specified time frame. Contract research is used by the industry to make use of university's research capabilities towards commercial benefits. The eighth mechanism is science park, research park, technology park, or incubators. Firms provide funds needed for carrying out research in an area near to university, in which all the facilities needed for research are present on it. The research is carried out by experienced and qualified personnel from both parties. The ninth mechanism is training. In this mechanism, knowledge is exchanged by different forms of training such as; transferring students into the industry to get familiar with the working environment, providing employees with a training about new technologies, and supplying managers with information and knowledge about administrative techniques.

Bekkers and Freitas (2008) illustrated different ways of knowledge transfer. Based on their observation, these knowledge transfer ways mentioned by Bekkers and Freitas (2008) can be considered as examples of the 9 knowledge transfer mechanisms, as mentioned by Lee and Win (2004). Bekkers and Freitas (2008) claimed that knowledge is exchanged between universities and industry through "knowledge transfer channels". They determined that there are 23 knowledge transfer channels between universities and industry as shown in Table 2.1. They reviewed the literature on the knowledge transfer channels, and they stated that there are different importance levels of knowledge transfer channels with respect to three considerations which are; industry sectors, scientific disciplines and basic knowledge characteristics, and organizational features. It was found that flow of students through employment and training, contract research, and collaborative research are very important knowledge transfer channels in engineering research field. According to scientific disciplines consideration, it was found also that flow of students between universities and industry, contract research, and collaborative research are very important in engineering discipline. According to organizational features, it was found that large firms would prefer collaborative research and contract research, while small firms would prefer flow of students through employment and training. On the other hand, it was found that researchers who work on applied research would prefer patents, and collaborative and contract research while researchers who work on basic research would prefer publications. However, Bekkers and Freitas (2008) recommended that there should not be a focus on using single transfer channel between both parties and to make use of the many other knowledge transfer channels.

Table 2.1. Knowledge transfer channels between universities and industry (Bekkers and Freitas 2008)

Transfer Channels
1. Scientific publications in journals or books
2. Other publications, including professional publications and reports
3. Patent texts, as found in the patent office or in patent databases
4. Personal (informal) contacts
5. University graduates as employees (B.Sc. or M.Sc. level)
6. University graduates as employees (Ph.D. level)
7. Participation in conferences and workshops
8. Joint R&D projects (except those in the context of European Union Framework Programs)
9. Students working as trainees
10. Joint R&D projects in the context of European Union Framework Programs
11. Contract research (excluding Ph.D. projects)
12. Financing of Ph.D. projects
13. Sharing facilities (e.g., laboratories, equipment, housing) with universities
14. Staff holding positions in both a university and a business
15. Flow of university staff members to industry positions (excluding Ph.D. graduates)
16. Licenses of university-held patents and 'know-how' licenses
17. Temporary staff exchange (e.g., staff mobility programs)
18. Personal contacts via membership of professional organizations
19. University spin-offs (as a source of knowledge)
20. Consultancy by university staff members
21. Specific knowledge transfer activities organized by the university's technology transfer office (TTO)
22. Contract-based in-business education and training delivered by universities
23. Personal contacts via alumni organizations

2.2.3 Advantages of Collaboration between Universities and Industry

There are a lot of advantages of technology transfer and collaboration between universities and industry (Lee and Win 2004). Both parties enjoy these advantages, which can be considered as motivations of starting collaboration between them. Advantages to university can be mentioned as follows: 1) serving the needs of economy and enhance its activities; 2) transferring students from universities and industry so that theoretical learning can be linked with practical experience; 3) accessing the industry for both basic and applied research; 4) enhancing the business status and reputation of industrial firms; 5) improving the implementation of new technologies; 6) developing new products; 7) saving the cost of R&D by using industry's support; 8) accessing protected markets; and 9) creating patents. On the other hand, advantages to industry can be mentioned as follows: 1) hiring qualified graduate students which are supplied by university; 2) involving the employees in different kinds of trainings; 3) accessing university's facilities and making use of staff's experience; 4) accessing research teams and making use of them for consultation purpose; 5) acquiring technical knowledge; 6) gaining technology services; 7) improving the quality of products; 8) saving costs; and 9) introducing new technologies to markets.

Hanel and St-Pierre (2006) investigated the importance of the cooperation between universities and industry, and clarified how this relationship is advantageous for both parties by reviewing the literature of collaboration between them, and stating examples of collaboration advantages. During the 1975-1978 period, the results of the collaboration between universities and industry were great (Hanel and St-Pierre 2006). The social return on university research investment was in the range of 28-40% (Hanel and St-Pierre 2006). The function of social return on investment (SROI) is defined by SROI Canada (2009) as follows: "SROI measures change in ways that are relevant to the people or organizations that experience or contribute to it. It tells the story of how change is being created by measuring social, environmental and economic outcomes and uses monetary values to represent them." On the other hand, the rate of return on industry research investment for private firms who were involved in collaboration with universities was 34.5% compared to 13.2% for those who were not involved in such collaborations (Hanel and St-Pierre 2006). In 1991, it was calculated that 10% of innovations between 1975 and 1985 would not have been created without the research input of university (Hanel and St-Pierre 2006).

It was mentioned in Statistics Canada's 1993 Survey of Innovation and Advanced Technology that collaboration of firms with universities is considered as the second most important source of new technologies which helps in introducing world first innovations (Hanel and St-Pierre 2006). Firms which collaborated with universities in R&D projects have many economic advantages than those who did not collaborate such as: 1) maintaining high competitive position among their peers; 2) maintaining a profit margin; 3) increasing their share in the international and domestic markets; and 4) increasing their profitability and adaptability (Hanel and St-Pierre 2006). In addition, it was found that 22% of firms which are collaborating with universities developed world first innovations versus 10% of non-collaborating firms (Hanel and St-Pierre 2006). Also, 50% of the collaborating firms developed Canadian first innovations versus 25% of non-collaborating firms (Hanel and St-Pierre 2006). Hanel and St-Pierre (2006) concluded that the most leading innovations are developed by firms who are engaged in partnerships with universities. This collaboration leads to a lot of economic benefits to collaborating firms compared to non-collaborating ones (Hanel and St-Pierre 2006).

2.2.4 Barriers to Universities and Industry Relationship

Many studies have investigated the collaboration between universities and industry but few studies investigated the barriers to this collaboration and how to reduce these barriers (Bruneel et al. 2010). Bruneel et al. (2010) claimed that there are two types of barriers to this collaboration which may exist; 1) orientation-related barriers, and 2) transaction-related barriers. First, the orientation-related barriers are those barriers that exist due to different orientations of industry and universities towards research. It was found that this type of barriers appears due to a lack in alignment of attitudes between both universities and industry. Cooperating firms often have problems with universities researchers regarding research topics or the disclosure form of research results. Universities researchers tend to work on research topics that are interesting and valuable to their peers, while firms tend to choose research topics which satisfy the needs of their customers and fulfill the target of new products development. Also, universities researchers work hard to produce a "leaky" knowledge to be recognized and appreciated by their peers, while firms try hard to keep the knowledge "sticky" for themselves to maintain a high competition with their peers.

Second, the transaction-related barriers are those barriers which exist due to conflicts over intellectual property and the way both firms and university administration deal with each other. The university targets to have its research carried out in the form of patents to create an intellectual property and use it for financial purpose. The university's research is commercially-oriented nowadays. It has been shown that there is a direct relationship between patenting and scientific performance, and that researchers who do an excellent research are also extraordinary in solving real world problems. However, some studies show that the increasing rate of patenting in universities has led to slow rate of research collaboration between universities and industry (Bruneel et al. 2010). In some cases, universities' goals to get financial benefits from their research have led to the occurrence of conflicts between universities and industry. These conflicts occur due to high expectations of the university about their research, which can lead to giving overvalue for their intellectual property (IP). This can lead to negative impact on the collaboration between universities and industry and discouraging the industrial firms from being involved with universities in research partnerships.

As an example of relationship barriers, Graham et al. (2011) analysed construction-related research and its relation with industry needs to investigate the orientation-related barriers. They claimed that the research should match the vision of industry to produce applicable concepts and meet the industry needs, and that research will be useful if it meets the construction industry needs. Based on that, construction professionals are encouraged to advise researchers on the topics to be explored, and direct them to the way which leads to their goal achievement as a result of research activities. They compared the ranks of research topics given by universities and industry. They reviewed the publications of four well known journals: *Journal of Construction Engineering and Management*, *Construction Management and Economics, International Journal of Construction Education and Research, and Associated Schools of Construction Annual Conference Proceedings*. They classified 607 research publications into 22 research themes, and they ranked them according to the number of occurrences of each research theme. However, it is worth mentioning that the authors believe that not all construction-related research is published in academic journals. Most of the construction research is performed as a company-specific research which is considered as consultation by universities (Graham et al. 2011). The results of construction company-specific research are considered to be confidential by the company, and the company may not allow these results to be published in research publications. Therefore, the authors stated that their study is focusing on the published research work and any company-specific research is not in the scope of their research. On the other hand, they asked the construction professionals to give a rank for each defined research theme. The online survey was sent to 414 construction professionals, in which 155 of the surveys were not answered. The comparison between research themes ranking is summarized in Table 2.2.

Table 2.2. Comparison of research themes rankings between universities and industry (Graham et al. 2011)

Research Theme	Industry Rank	Research Rank
Constructability	1	17
Estimating/Bidding	2	6
Economics/Cost Control	3	4
Design/BIM	4	8
Materials/Equipment	5	18
Project Delivery	6	15
Management/Risks	7	2
Performance	8	9
Safety	9	9
Productivity/Optimization	10	16
Technology/Innovation	11	3
Project/Quality Management	12	19
Procurement	13	21
Computer Systems/Expert Systems	14	14
Legal/Contracts	15	12
Facilities Management	16	20
Scheduling	17	7
Sustainability	18	13
Heavy Civil Construction	19	21
Training/Human Resources	20	1
Industry Overview - A look at the industry in general, such as the history, progress, or trends	21	11
Globalization	22	5

Unfortunately, it was found that there is no correlation between most of the research carried out by researchers and the needs of construction industry (Graham et al. 2011). The research is oriented far away from the industry needs, in which there is a disconnection between researchers and construction industry professionals. It was found that research related to training and human resources was ranked the first according to universities perspective. The training and human resource research focuses on education and training of students in the construction industry. This indicates that researchers in universities are focusing their research to improve their academic work. Also, it indicates that universities want to improve their techniques and collaboration with the industry by graduating qualified students who have a practical experience. In addition, the industry ranked training and human resources as the 20th may be because the industry believes that this research topic has been widely investigated and its results were effective (Graham et al. 2011). On the other side, constructability was ranked the first according to industry perspective while it was ranked as the 17th according to universities perspective.

The authors stated that researchers should focus more on doing research related to constructability to meet the needs of construction industry based on the given ranks. Graham et al. (2011) found that some of the research carried out by universities is not important to the construction industry. It is worth mentioning that there were some research themes which were highly ranked by both universities and construction industry such as; estimating, economics, management and design. In other words, still there is a common agreement between universities and industry on some research themes.

2.2.5 Mitigating the Barriers to Universities and Industry Relationship

Bruneel et al. (2010) investigated three mechanisms to reduce the barriers of collaboration between universities and industry. These three mechanisms are; experience of collaboration, breadth of interaction channels, and inter-organizational trust. First, it was found that experience of collaboration helps in reducing both oriented-related and transaction-related barriers. Industrial firms have to set operating routines and practices to manage their collaboration with the university and to make this collaboration serves their needs. Industry's expectations about the delivery time and form of the results of research collaboration may be controversial with the university; however, the operating routines and practices used in this collaboration can be adjusted to be used later efficiently in future collaborations. In other words, firms learn from their previous collaboration experience and improve their way of involvement with the university in the future. Also, this experience of collaboration helps in developing a common understanding between universities and industry and closes the gap between them. In addition, experience of collaboration mitigates transaction-related barriers. Experienced industrial firms which have been involved with the university in many research projects know how to negotiate on an intellectual property (IP) contracts with university. These firms are knowledgeable about different IP systems within different universities which can help them to negotiate in a successful way with the university on IP.

Second, it was found that breadth of interaction channels (knowledge transfer channels) works on mitigating oriented-related barriers; however, it increases transaction-related barriers. Industrial firms interact with university in research projects through different formal and informal knowledge transfer channels which have been previously discussed in this chapter in the "forms of knowledge transfer between universities and industry within R&D projects" section. Using different knowledge transfer channels leads to a clear understanding of the interaction between both parties by enhancing the transfer of rich amount of knowledge through these different forms (channels). It also leads to mitigation of oriented-related conflicts, by enhancing the firm's ability to align different incentive systems within the collaboration. In addition, it leads to alignment of attitudes between universities and industry and closes the gap between them by using informal short-term interactions as an initial step for collaboration. These informal interactions do not need a formal contract, and they lead to a better and effective development of long term research collaboration and formal agreements between the two parties. On the other hand, using different knowledge transfer channels lead to the appearance of transaction-related barriers. Interaction of industrial firms with many divisions of the university through different channels, especially the formal ones, may lead to high engagement with university's administration and its rules and procedures, and this may lead to occurrence of conflicts. In addition, transaction-related barriers also appear when the benefits of outcomes of partnership projects are to be distributed amongst the industrial firm and different divisions of the university, which may cost the firm expensive negotiations about follow-on rewards from the project with different university divisions.

Third, it was found that inter-organizational trust mitigates both oriented-related barriers and transaction-related barriers. Trust makes partners of a relationship sure that this collaboration is based on mutual benefit, common understanding, and cooperation on solving any problems. Also, trust works on enhancing the relationship between both partners, in which commercial sensitive information flow between them. If trust level is low between both partners, they will be discouraged to share information and knowledge which are required to achieve a successful collaboration. In addition, trust between parties leads to alignment of their attitudes, reaching common understanding, and closing the gap between them.

2.3 Literature Review of Logic Models

2.3.1 What are Logic Models?

Logic models have been developed over the past 30 years and they are utilized in planning, implementing, and evaluation of programs. Logic models are used in different contexts. They are used in developing and implementing health research-community partnerships (Fielden et al. 2007), and in performance management of national drug control program in the US (Millar et al. 2001). In addition, they are used in applying for grants to evaluate and monitor funded programs and to ensure their performance efficiency (Fielden et al. 2007). Also, they are used in the Canadian health domain. For example, they are used in Alberta to evaluate the provincial primary health care system and maintain its efficiency (Primary Health Care Branch 2013), and they are used in Ontario to plan and evaluate health care programs and improve their quality (Quality Improvement and Innovation Partnership 2010).

Additionally, logic models are used by some governmental bodies in Canada such as the Treasury Board of Canada Secretariat to evaluate the program performance and manage expenditures (Treasury Board of Canada Secretariat 2010). O'Keefe and Head (2011) stated that Lifecycle logic model has been developed by one of the Flagships of the Commonwealth Scientific and Industrial Research Organization (CSIRO) to be used in large scientific research programs. The CSIRO consists of ten Flagships in which each Flagship consists of different research projects and teams to solve a national problem in one of the different research areas such as energy, water and health. The CSIRO Preventative Health National Research Flagship developed Lifecycle logic model to plan for the desired outcomes and impact of the research programs in order to address national needs, and evaluate program performance. This logic model was developed to suit different research activities within the Preventative Health Flagship and in all other Flagships. This Lifecycle logic model starts with identifying the needs of the research program based on a national challenge then it identifies the investment in the program, and continues its path with program implementation until it reaches the resulted outputs and desired impact to meet the needs of the program. After that, unmet needs are investigated which help to update the Lifecycle logic model components in another cycle in order to reach desired impact which can satisfy the unmet needs of the program. This lifecycle logic model is developed by program participants to integrate their different expectations and perspectives of the program, and reach common understanding of the program's components (i.e., inputs, outputs, and outcomes) between program participants.

A logic model was also used by The Evidence Network (TEN) to evaluate the impact of different research programs on companies. TEN developed a specific logic model named "TEN's Innovation Intermediary Logic Model" to evaluate the impact of different research programs from the perspective of companies (TEN 2010; TEN 2012). For example, this logic model was used by TEN to evaluate the impact of Canada's Tri-Agency College and Community Innovation Program (CCI) on companies (TEN 2012). The CCI program is supported by three federal government agencies in Canada: the NSERC, the Canadian Institutes of Health Research (CIHR), and the Social Sciences and Humanities Research Council of Canada (SSHRC). This program supports the Canadian colleges with funds to carry out research activities and benefit companies with the research results. TEN depended in the assessment methodology on developing questionnaires based on the defined logic model to be sent to the companies in order to evaluate the impact of the CCI program on the companies' development. Similarly, TEN used this logic model to evaluate the impact of Global Access Program (GAP) on Finnish companies (TEN 2010). The GAP program works on connecting highly qualified students from the Fully Employed MBA program at the University of California at Los Angeles (UCLA) with existing companies to help these companies in developing business strategies. TEN used the defined logic model to develop questionnaires for assessing the impact of the GAP program from the perspective of the Finnish companies.

Logic models have been used effectively over the last two decades by evaluators and program managers to assess the efficiency of programs; they are able to provide program managers and evaluators with a ready plan for evaluation (McCawley 2001; Dwyer and Makin

1997). They schematically express the relationships between what is invested in a program, what is done through the program, and what has been achieved as a result of this program (Dwyer and Makin 1997). W.K. Kellogg Foundation (WKKF) (2004) defined the logic model in its Logic Model Development Guide as “a systematic and visual way to present and share your understanding of the relationships among the resources you have to operate your program, the activities you plan, and the changes or results you hope to achieve”. Logic models are widely used in evaluating different programs to determine the occurrence of expected results/outcomes from collaboration in research projects. They consist of inputs, outputs, and outcomes, which are connected together by causal relationships (Millar et al. 2001). “If-then” causal relationships are used to link inputs with outputs and outputs with outcomes (Taylor-Powell and Henert 2008). Logic models help in clarifying and visualizing the connections between the resources invested in a program, the processes carried out through the program, and the expected end results achieved (Millar et al. 2001). They are sometimes called “program theory” or “theory of action” because they show how programs should work to achieve the desired outcome (University of Wisconsin-Extension (UWEX) 2003). Logic models provide the program’s participants with a clear image of the program path starting by the planned work through a program moving towards the desired results using casual “if-then” relationships (WKKF 2004).

2.3.2 Types of Logic Models

There are different types of logic models investigated in the literature. Each type is used for specific purpose. The main purposes of using logic models are evaluation, implementation, and planning and design of a program. Examples of logic models’ different types were presented by WKKF (2004) in its Logic Model Development Guide. Logic models can be classified into “theory approach models”, “outcome approach models” and “activities approach models” (WKKF 2004). The “theory approach models” are considered as conceptual models while “outcome approach models” and “activities approach models” are considered as applied models. No certain type of logic models serves all needs; therefore, successful selection of a logic model type is based on the purpose of using the logic model and the status of the program whether it is in progress or it has yet to be initiated. Theoretical approach models are used for initiating and planning a program, outcome approach models are used for evaluating an ongoing program and activity approach models are used for implementing the planned program.

First, Theory approach models focus on theory of change or the purpose of designing and planning a program. UWEX (2003) stated that theory of change is “a description of how and why a set of activities−be they part of a highly focused program or a comprehensive initiative−are expected to lead to early, intermediate and longer term outcomes over a specified period.". Theory approach models focus on the assumptions at the beginning of the program, which explain the specific reasons for initiating a program. They are mainly used to plan and design a program by identifying the reasons behind a program implementation (WKKF 2004). These models’ components are built based on the assumptions and thoughts clarified and stated at the beginning of the program. Second, Outcome approach models focus on linking the inputs and activities by using causal relationships with the desired outcomes in an ongoing program. These models do not write or state the theory of change explicitly, but the theory of change is taken in consideration while thinking of the logic model itself. This type of models focuses on defining and achieving the desired results (short-term outcomes, medium-term outcomes, and long-term outcomes/impact) through the implementation of the program by using the invested resources and carrying out the planned activities (WKKF 2004). Outcome approach models are the most suitable models used in evaluation and assessment of program’s efficiency (WKKF 2004). Third, activity approach models focus on identifying the planned activities to implement the program successfully. They focus on describing in detail the different activities that should be carried out to reach the desired results efficiently. These models explain the intentions of what is going to be done through program’s implementation by planning different activities. Activities are described in a detailed way to lead to the desired outcomes. These detailed activities are useful for monitoring and managing progress efficiency throughout program implementation by monitoring which activities have been carried out as planned.

2.3.3 Different Structures of Logic Model

There are slightly different structures of logic models proposed in the literature by different organizations like; UWEX (Taylor-Powell and Henert 2008), University of Idaho-Extension

(UIEX) (McCawley 2001), WKKF and United Way of America (UWA). The first type (type 1) is proposed by WKKF and UWA. They use the same structure in which outputs are the products of activities as shown in Figure 2.1 (WKKF 2004; UWA 1996). On the other hand, the second type (type 2) is proposed by UWEX and UIEX. They define outputs as the activities carried out by different participants in the program, and they use the products of activities as indicators of achievement to be used in answering the evaluation questions in the program's evaluation plan, as shown in Figure 2.2 (Taylor-Powell and Henert 2008; McCawley 2001). The structure of the logic model proposed by UWEX and UIEX is convenient because it uses the activities' products as indicators of achievement in the evaluation process of the such programs , and this provides the evaluators with information which help them to clearly evaluate the program and answer the evaluation questions fairly (Taylor-Powell and Henert 2008). The meaning of different logic models' components are explained and summarized in Table 2.3 and Table 2.4 below.

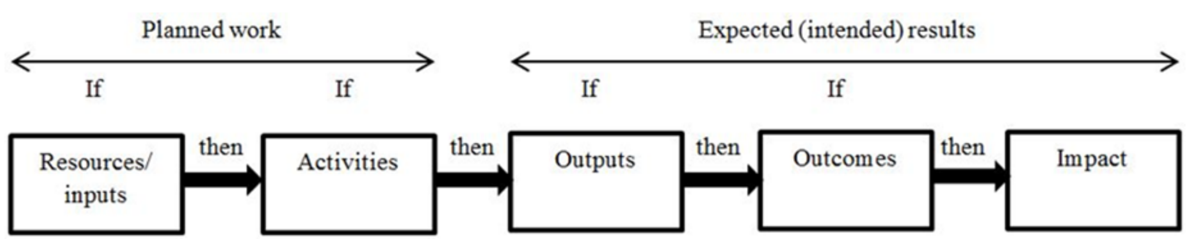

Figure 2.1. The logic model of WKKF and UWA (adapted fromWKKF (2004) and UWA (1996))

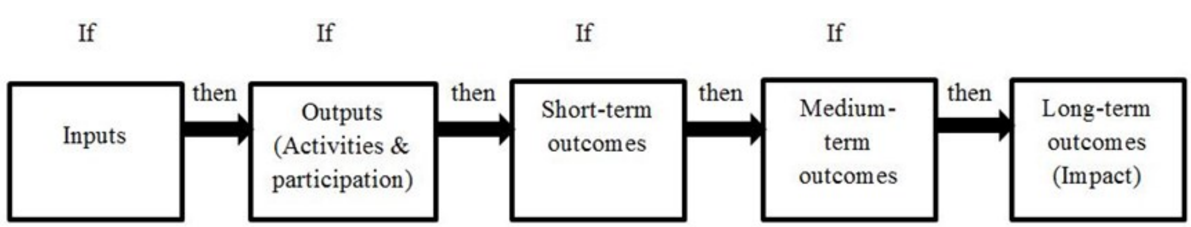

Figure 2.2. The logic model of UWEX and UIEX (adapted from Taylor-Powell and Henert (2008) and McCawley (2001))

Table 2.3. Type 1 logic model basic components

(WKKF 2004; UWA 1996)

Components	Definition
Resources / Inputs	The investment in the program such as funds, people, and time.
Activities	The different completed actions done through the program implementation such as events and processes
Outputs	The results of carrying out program activities such as number of meetings held, published materials and number of classes delivered
Outcomes (short-term and medium-term)	Short-term outcomes are the results of the program within 1-3 years, such as change in awareness and knowledge. Medium-term outcomes are the results of the program within 4-6 years, such as change in behaviours, practices, technologies and actions.
Impact	The long-term results of the program within 7-10 years, such as the changes in social, economic, and environmental conditions.

Table 2.4. Type 2 logic model basic components

(Taylor-Powell and Henert 2008; McCawley 2001)

Components	Definition
Inputs	The investment in the program like funds, people, time, skills and experience.
Outputs (Activities & participation)	The completed activities carried out like conferences, workshops and publications. Also, the people who are reached like clients, organizations and decision makers.
Short-term outcomes	The results of the program directly after the outputs. They include change in awareness, knowledge, skills, motivation and attitude.
Medium-term outcomes	The results of the program after the occurrence of short-term outcomes. They include change in behaviours, practices, technologies, policies, actions and management strategies.
Long-term outcomes (impact)	The results of the program after the occurrence of medium-term outcomes. They are often called impact like the changes in social, economic, political and environmental conditions.

2.3.4 Benefits and Advantages of Using Logic Models

The literature investigated a lot of benefits of using logic models in program implementation and evaluation processes. Dwyer and Makin (1997) claimed that a logic model is beneficial as follows: 1) it visualizes the program and make it understandable to stakeholders; 2) it shows the interrelationships between the program's inputs and results; and 3) it is considered as an integration of program planning and evaluation. Dykeman et al. (2003) added that logic models are helpful in the follows: 1) guiding the evaluation of outcomes; and 2) determining whether the outcomes meet participants' expectations or not. Also, Millar et al. (2001) clarified that logic models help to: 1) identify external factors that may act as obstacles to reach desired end results; 2) reach consensus and common agreement within program's participants on program's inputs and outputs to reach expected outcomes; 3) improve the communication between stakeholders for a better development and evaluation of a program; and 4) provide an approach to select other alternatives to achieve the desired goals of the program. In addition, McLaughlin and Jordan (1999) claimed that logic models are useful for: 1) improving the program to reach desired outcomes; and 2) identifying key performance indicators that are used in the evaluation process.

2.3.5 Developing Logic Models

There are different approaches to develop a logic model for a program based on the aforementioned purposes, and a logic model can presented using different formats such as tables and flowcharts. Different program participants have different perspectives about what they invest in a program, what should be done through program implementation, and what are the expected outcomes of implementing a program. As such, logic models are best developed using a group of program participants to develop a successful, effective model that integrates the different visions and perspectives of participants. Logic models can be presented in the format like flow charts or tables according to the preference of participants who will use it, and its clarity and simplicity (Taylor-Powell and Henert 2008). WKKF (2004) and UWA (1996) advised to develop the logic models in backwards way. It means that the expected outcomes and impact have to be defined to identify the activities needed to reach them. Finally, the invested resources needed to carry out activities can be defined. Millar et al. (2001) clarified that the backward approach is the most suitable one to develop a logic model used for evaluation purpose. On the other hand, UWEX (2003) proposed two ways to develop logic models either to work backwards like the aforementioned approach or start with identifying the invested resources and work forwards to reach the intended outcomes of the program. UWEX (2003) clarified that the backward approach starting with defining outcomes is most suitable for program planning and development, while the forward approach starting with defining inputs/resources is the most suitable for program evaluation and assessment.

The difference between the two approaches was further investigated by Rush and Ogborne (1991). They said that the logic model used for evaluating an ongoing program usually starts with two questions which are "(1) what is done and (2) what are the changes intended to be achieved?" They claimed that an evaluator should apply a "top-down" approach which is the same as the forward approach mentioned by UWEX (2003). It means that the evaluator starts his or her evaluation by the invested resources until reaching the expected outcomes. On the other hand, they clarified that the backward method is suitable for planning a new program and usually this type of logic model start also with two questions, which are "(1) what are the intended or expected changes and (2) how are they going to be achieved?".

2.3.6 Using Logic Models in Evaluation and Assessment

Logic model is a tool that can describe the story of a program since its start until the outcomes have been achieved (McLaughlin and Jordan 1999). It helps in building common agreement between program participants on expected program performance (American Evaluation Association (AEA) 2015). It guides the evaluators on how to assess the outcomes and improve the program quality (McLaughlin and Jordan 1999). Logic models have been used over the last two decades for the purpose of program evaluation to assess the outcomes in terms of what should have been achieved and what has not been achieved as expected (Millar et al. 2001). Patton (1997) defined evaluation as "the systematic collection of information to make judgements, improve program effectiveness and/or generate knowledge to inform decisions about future programs". Evaluation is essential to help program participants in making decisions at every point in a program's life cycle (AEA 2015). There are four main purposes of evaluation, which are accountability, advocacy, allocation, and analysis (program improvement and learning). First, accountability aims to show that the funds and other resources invested in a program have been used in an effective and efficient way. Second, advocacy aims to show the benefits of supporting research, and demonstrate the research activities and processes among program participants. Third, allocation aims to specify where to assign funds and investments of the program in the future for the best use of funds and resources. Fourth, analysis aims to demonstrate how and why research is effective and how it can be better developed. Schalock and Bonham (2003) stated that the main obstacles for evaluating and assessing program's outcomes are: 1) lack of an evaluation plan and assessment methods to evaluate the expected outcomes of program partners and improve the program; 2) lack of the experience in developing logic models that help in drawing the interrelationships between inputs, outputs, and outcomes; and 3) a feedback mechanism that helps to improve the quality of a program and its performance.

Evaluation planning is important to achieve the systematic evaluation of a program (AEA 2015). Evaluation planning is responsible for organizing the evaluation activities according to a logical framework (i.e., logic model) that describes the logic or theory of change of a program (AEA 2015). Constructing the evaluation plan on the basis of the logic model helps in ensuring that the indicators (i.e., metrics) used in answering the evaluation questions are linked to inputs, outputs, and outcomes of the program. Evaluation planning requires the identification of responsibilities, approaches and techniques, metrics, data requirements, data collection and analysis methods, and reporting mechanisms as investigated in the following paragraphs. The AEA (2015) developed a generic logic model and a menu of different indicators (i.e., metrics) which can be used for evaluating research, technology and development (RTD) programs components as shown in Table 2.5. This generic logic model can be applied to RTD programs in various domains.

Table 2.5. Examples of indicators used in evaluating RTD programs (AEA 2015)

Program's Components	Indicators/Metrics
Inputs	• Expenditures on research •Expenditures on research support activities, such as database development, research planning and priority setting • Depth, breadth of knowledge base and skill set of researchers and technologists, teams, organizations • Capabilities of research equipment, facilities, methods that are available • Vitality of the research environment (management, organizational rules, etc.)
Outputs (i.e.,	• Plan, select, fund, researchers, research projects, programs • Quality, relevance, novelty, of selected researchers, projects, programs

Program's Components	Indicators/Metrics
Activities)	• New knowledge advances (publications, technical challenges overcome) • Quality and volume of other outputs (grants made, projects completed, number of reports, people trained, etc.)
Short-term Outcomes	• Citations of publications; patent applications, patents • Awards, recognition, professional positions • Expansion of Knowledge base in terms of technical leadership and absorptive capacity • Advances in research/technical infrastructure (new research tools, scientific user facilities, testing facilities) • People educated in RTD area and research methods • Linkages/communities of practice/networks • Technical base (technology standards, research tools, databases, models, generic technologies) • Commercialization/utilization support base (manufacturing extension programs, supportive codes, etc.)
Medium-term Outcomes	• New technology development advances (movement through stages, functionality) • Product commercialized; policy /practice implemented; attitude or behaviour changed • New "technology" commercialization/diffusion advances (supply chain develops, adoption of new process technology)
Long-term Outcomes (i.e., Impact)	• Modeled monetized benefits • Health status • Security, safety measure • Sustainability measure • Income levels • Jobs • Benefit to cost ratio • Quality of life • Environmental quality • Production levels • Cost savings • Competitiveness

Logic models are not used only for evaluating outcomes of a program. Taylor-Powell and Henert (2008) clarified that logic models can be used for evaluating four different aspects; needs/asset assessment, process evaluation, outcomes evaluation, and impact evaluation. Also, WKKF (2004) stated that logic models can be used to evaluate context (relationships and capacity), implementation, and outcomes (short-term, medium-term, and long-term/impact). Both aforementioned references identified the same areas of evaluation, and the only difference is that WKKF (2004) included the impact and outcomes as one area of evaluation, while Taylor-Powell and Henert (2008) separated them as two different areas of evaluation. Taylor-Powell and Henert (2008) stated that needs/asset assessment focuses on the purpose of the program and the investments needed to reach goals. Process evaluation focuses on the implementation status of planned activities that should be carried out through the program, and whether the program participants have been reached or not. Outcomes evaluation focuses on the fulfillment degree of expected results, what has been achieved and what has not been achieved, who is receiving benefits, and what unexpected outcomes have occurred. Impact evaluation focuses on the social, economic, and environmental changes that have occurred in the long term as a result of the program, and whether the program is worth the resources which have been invested or not.

The outcomes and impact evaluation of a program partnership clarifies whether this partnership is making any difference and if it is worth the investments or not based on the program participants' perspectives (Taylor-Powell et al. 1998; AEA 2015). Evaluation questions of outcomes address two aspects which are: 1) outcomes for individual members and the collaborating organizations; and 2) outcomes of the partnership itself. Examples for evaluation questions of first aspect are: What differences happened as a result of my involvement in the project? What would have happened without my involvement? What benefits did the collaborating organizations gain? What credits can be awarded to me or us as a group of collaboration? Examples for evaluation question of the second aspect are: What are the results or the changes that occurred as a result of collaboration? What are the differences? For whom? How and have any unexpected outcomes occurred as a result of collaboration? Therefore, the evaluation questions are designed by program participants based on their expectations for the outcomes of this collaboration. UWEX (2003) stated that there are two types of evaluation question. The first type is formative questions, which are asked within an ongoing program to improve the program's quality. The second type is summative questions, which are asked after the program has been finished to evaluate what has occurred efficiently. Summative questions are used to decide whether to continue or not in a program partnership.

Taylor-Powell et al. (1998) claimed that evaluation can be carried out by different people based on the preference of program participants. First, the evaluation can be carried out by a member or team of members assigned by program participants to take evaluation leadership. This team communicates on a regular basis with program participants to ensure their involvement in the evaluation; however, the evaluation tasks are carried out by the evaluation team. Second, all program participants share in planning for the evaluation process, and evaluation tasks are assigned to certain group members. One member is often assigned a leadership position in the evaluation process to ensure that evaluation tasks are completed; however, all the program participants are responsible for making decisions and controlling the evaluation process. Third, program participants can hire a consultant to advise them about the evaluation process and to do most of the evaluation planning and data collection needed; however, the evaluation itself is carried out by program participants. Fourth, the program funder makes an agreement with an external evaluator who is responsible for evaluation planning and carrying out the evaluation of the program. Fifth, an individual of the program participants may want to carry out an evaluation for the accountability needs of his or her agency. He or she may carry out the evaluation only by himself or herself or ask for other participants' inputs and assistances; or the program participants' apply his or her plan and carry out the evaluation together as a team.

Taylor-Powell et al. (1996) provided a guide to help evaluators in planning for program evaluation with four definite steps. The evaluation plan can be implemented after developing the logic model. The four steps of an evaluation plan are: 1) focusing the evaluation; 2) collecting the information; 3) using the information; and 4) managing the evaluation. Focusing the evaluation step can be achieved by defining the follows: what is going to be evaluated; purpose of evaluation; users of evaluation and their intentions of using this evaluation; the questions used through the evaluation process of different criteria; the indicators (i.e., metrics) needed to assess the outcomes and answer the evaluation questions clearly; and the resources (time, money, people, etc.) needed to carry out the evaluation process. Collecting the information step is concerned with the information needed to answer the defined evaluation questions of different criteria. This information is what needs to be used as indicators (i.e., metrics) for answering the evaluation questions, in which the information can be qualitative or quantitative. An indicator (i.e., metric) is considered as the evidence that indicates what you need to know to answer evaluation questions; it is the measurement that helps you to answer the questions of evaluation (UWEX 2003). This step can be achieved by defining the sources of this information (existing information, participants, observations, etc.), data collection methods (surveys, focus group interviews, case studies, etc.), and the point in time of collecting the data throughout the project.

Using the information step is concerned with representing the data in an understandable and clear way to be used as efficient indicators for answering evaluation questions. This step can be achieved by the following: analysing different types of data (qualitative and quantitative), explaining the meaning of the collected data and giving a clear interpretation for it; and communicating and sharing the findings of the evaluation with the program participants in different forms of communications like (graphs, charts, reports, etc.). The final step is managing the evaluation by defining appropriate timeline for the evaluation process and assigning a reasonable budget to carry out the evaluation plan.

2.4 Other R&D Evaluation Methods

Besides using logic models in evaluation of R&D programs, there are other methods applied to evaluate R&D programs. For example, Alberta Innovates – Health Solutions (AIHS) (2015) developed *"Health Research to Impact" Framework* to assess the impact achieved through the investments of AIHS in the health research. The goal of this framework is to demonstrate the impact of AIHS's investments ranging from academic impacts to social and economic impacts (AIHS 2015). This is achieved through the application of a methodology to assess the impact for the purposes of accountability and transparency to the public, and learning and enhancing the awareness level of the research and innovation benefits. In addition to demonstrating the impact of the research at AIHS, AIHS aims to use this framework to increase the benefits from the investments of its research by using the evaluation of the impact to make decisions about its funding activities and to work closely with their program partners, stakeholders and the health research community to fulfill better results regarding health and prosperity for Alberta citizens.

The *Health Research to Impact Framework* is developed by AIHS (2015) to follow the research status starting from investments to intended results. It helps AIHS in evaluating whether its different activities are relevant (i.e., strategically aligned; meet the addressed needs), effective (i.e., meet AIHS's mission; fulfill their objectives and outcomes), and efficient (i.e., timeliness; increase cost to benefit). This framework consists of AIHS's inputs which are connected directly to the targeted collection of outcomes as shown in Figure 2.3. The AIHS used the impact data collection system called "Researchfish" to express the intended outcomes (i.e., results) of the health research program. The Researchfish has been introduced by the Medical Research Council in the United Kingdom and used by more than 62,000 researchers all over the world (AIHS 2015).

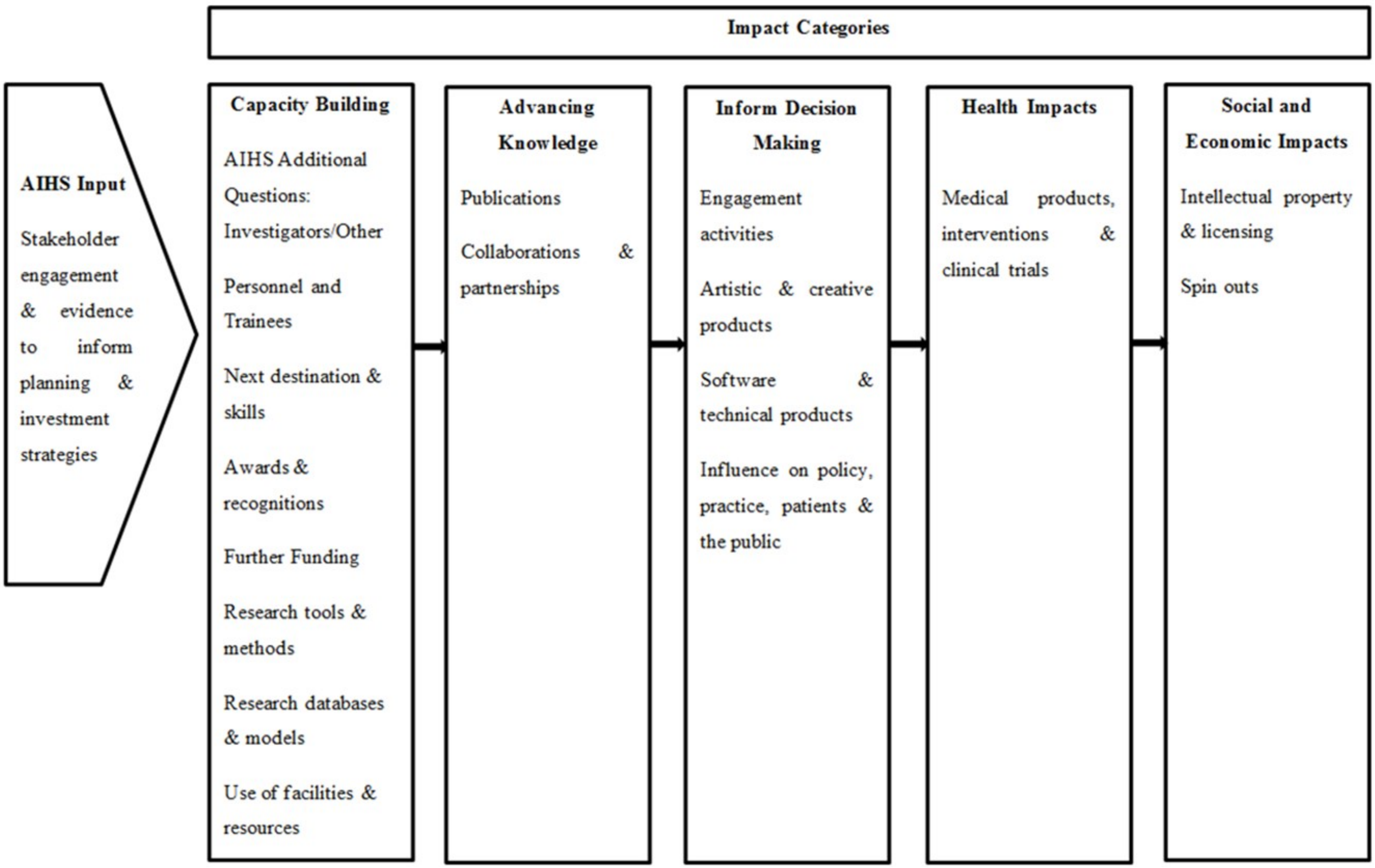

Figure 2.3. The *Health Research to Impact Framework (*adapted from AIHS (2015))

However, the *Health Research to Impact Framework* is different from logic models. First, the *Health Research to Impact Framework* does not state the activities carried out within the program and the program's participants separately. It specifies impact to outputs (i.e., activities) and outcomes, whereas logic models specify impact to outcomes and/or long-term outcomes and it clearly states the outputs (i.e., activities) separately. Second, the outcomes stated in the *Health Research to Impact Framework* are not classified as short-term, medium-term, and long-term outcomes. The outcomes categories, following Canadian Academy of Health Sciences (CAHS) (2009) framework, are classified as follows: capacity building, advancing knowledge, informing decision making, health impacts, and social and economic impacts. There is no clear separation between outcomes in terms of time. Therefore, it is obvious that logic models are better than the framework proposed by AIHS (2015) as it clearly states the different program's components and ensure the clear separation between them, which enables the program's participants to clearly understand and visualize the theory of the program to be evaluated.

Roussel et al. (1991) developed an R&D evaluation model called "third-generation R&D management" to manage and evaluate a portfolio of R&D projects within a corporation. This model is used by industry companies to allow general managers and R&D managers to share their visions in deciding what R&D to do or not to do. Third-generation R&D management is a conceptual model that enhances working relationships by allowing different managers to share their insights towards the betterment of R&D activities within the corporation. Using third-generation R&D management, different managers within the corporation can measure costs, benefits, and risk/reward of different R&D projects within the corporation to better allocate the resources used in the R&D. The third generation R&D management model consists of six operating principles as shown in Figure 2.4, in which these operating principles help the R&D managers in managing and evaluating the R&D progress. However, the third-generation R&D management model is different from logic models. First, the third-generation R&D management model does not state the activities carried out within the program and the program's participants clearly. Second, there is no clear definition of the intended results of the program. The outcomes are not clearly classified in the third-generation R&D management model to help users to easily assess the outcomes as short-, medium-, and long-term outcomes. Third, the model does not provide an approach how to measure the results and evaluate the progress of the program.

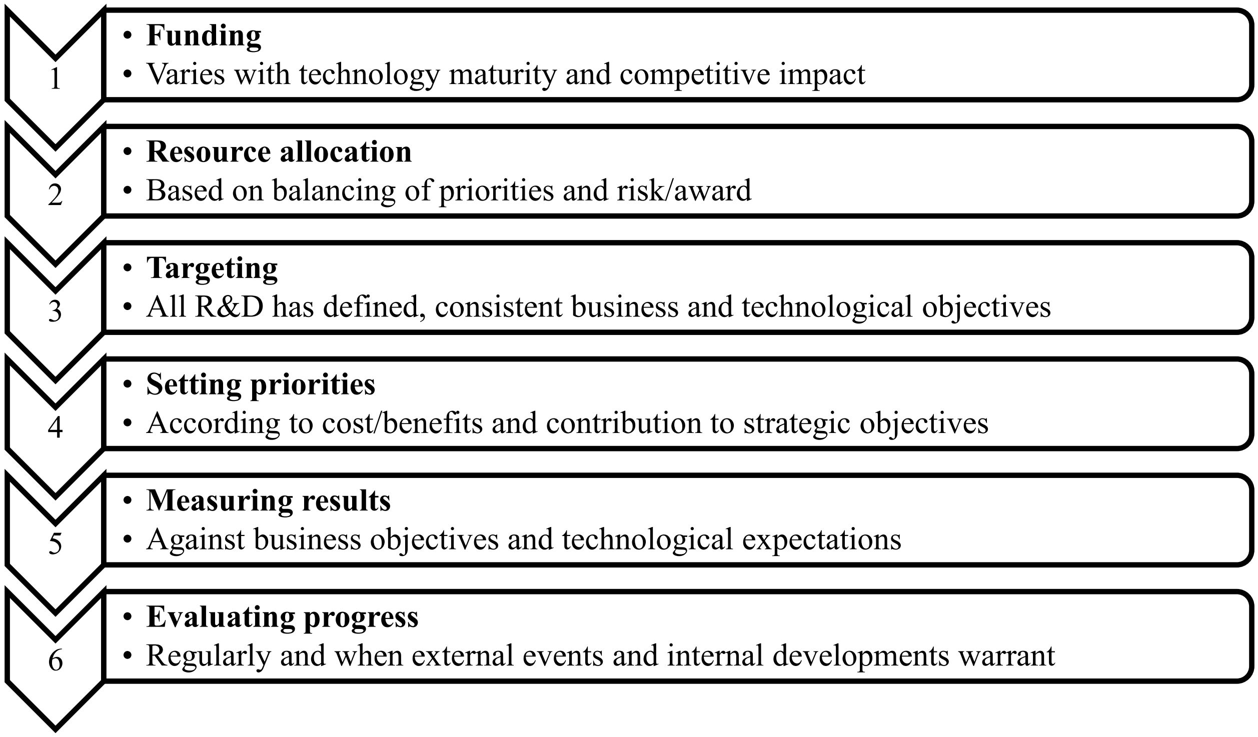

Figure 2.4. The operating principles of the third-generation R&D management (adapted from Roussel et al. (1991))

2.5 Concluding Remarks

Universities and industry groups are strongly linked through R&D projects. There are a lot of advantages to both universities and industry as a result of collaboration in research programs. For example, universities and research centers get the benefit of patenting, developing new products, improving technologies, and accessing the industrial field for applying their research. On the other hand, industry partners get the benefit of hiring qualified graduate students, accessing university's facilities and research centers, using the university staff as consultants, improving the quality of products, and saving costs. The literature has investigated the collaboration between universities and industry in R&D projects. It shows that the support of the Canadian construction industry to R&D projects is decreasing over the years, which lead to a relatively weak performance of R&D projects in Canada nowadays. Consequently, this may affect the relationship between universities and industry in the long term. University research is the source of innovation and development. Therefore, the industry needs to develop a strong collaboration with universities research teams to develop new products, increase their profit, and maintain a high competition among their peers. The industry can strongly enhance R&D programs by investing more funds on the research partnerships with universities. In addition, barriers to the relationship between universities and industry have been investigated in this chapter which are; oriented-related barriers, and transaction-related barriers. These barriers can be reduced by three mechanisms which are: good experience of collaboration, breadth of interaction channels between universities and industry, and high level of inter-organizational trust between universities and industry.

The literature showed many examples of applying logic models in different contexts. As previously mentioned in this chapter, logic models have been widely used in the health research domain. They were used to develop health research programs, implement them, and evaluate their performance. Logic models can help in reaching consensus and common agreement between program participants on the investments and activities within a program to reach the expected outcomes. Despite the different advantages of applying logic model in development and evaluation of program, logic models have not yet been applied in the construction research domain.

Based on the aforementioned advantages of the R&D collaboration, its challenges, and the aforementioned benefits of logic models, it is necessary to apply logic models in the construction domain to better develop, evaluate, and improve the partnership between the collaborating parties. Logic model helps in evaluating program outcomes. This can be achieved by integrating the logic model with an evaluation plan to construct an evaluation framework for assessing the different components (i.e., inputs, outputs, and outcomes) of the R&D partnership. If the expected outcomes are not achieved, the program can be enhanced by improving the inputs and outputs of different parties. In addition, it helps in defining and building a common agreement on the requirements from each party of collaboration to fulfill successful end results. Also, logic model enhance the communication between program partners. This may help in aligning the attitudes of program partners and closing the gap between universities and industry, which may lead to mitigation of barriers to the relationship between both parties.

In the next chapter, a generic logic model for R&D programs and generic submodel for Industrial Research Chairs (IRCs) within NSERC IRC program are proposed. Different criteria are listed within the models to represent the investment of program participants', the activities carried out by them within the collaboration, and their expected outcomes as a result of the program.

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CHAPTER 3 PROPOSED LOGIC MODELS FOR R&D PARTERSHIPS[3]

3.1 Introduction

The logic model is useful for representing program partnerships. It shows the link between the invested resources and outcomes of a partnership (McLaughlin and Jordan 1999). The components of a partnership are well represented using a logic model to show how collaboration between parties works. The logic model tells the story of a partnership through investigating the partnership components which are; resources (inputs), activities and people reached (outputs), short-, medium-, and long-term outcomes. The logic model has a lot of benefits such as: 1) improving communication among partnership participants and building consensus and common agreement of inputs, outputs, and expected outcomes of a partnership; and 2) planning, improving, and evaluating a partnership, and representing the links between its components (McLaughlin and Jordan 1999). Each logic model component is represented by a list of criteria used in the evaluation of a program. The different criteria listed in a logic model are evaluated with different metrics. These metrics can be qualitative or quantitative metrics (Hauser and Zettelmeyer 1996). Different scales are assigned to metrics to measure them. Types of scales assigned to the metrics depend on the metrics' types whether they are qualitative or quantitative (Rea and Parker 1997).

This chapter presents a proposed generic logic model which describes the collaboration between the three parties of R&D partnership (i.e., university, industry, and government). This generic logic model can be applied to different R&D partnerships for evaluation purpose. Also, this chapter presents a proposed generic submodel, which describes R&D collaborations between university, industry, and Natural Sciences and Engineering Research Council of Canada (NSERC) through the Industrial Research Chair (IRC) program. This proposed submodel clearly refines and tailors the role played by the three collaborating parties in the generic logic model to suit the role played by them in R&D partnerships within the NSERC IRC program. Besides, this

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chapter presents the different types of metrics and corresponding scales which can be used to assess the different criteria listed in the proposed submodel. This submodel is used in a pilot study, as investigated later in Chapter 4, to evaluate a construction R&D partnership specifically the NSERC IRC in Strategic Construction Modeling and Delivery (SCMD). Examples of the metrics used for measuring the criteria for inputs, outputs, and outcomes of the proposed submodel have been investigated in this chapter.

3.2 Criteria for Inputs, Outputs, and Outcomes of R&D Partnerships

The basic components of the logic model, according to the structure of logic model investigated by Taylor-Powell and Henert (2008) and McCawley (2001), are as previously mentioned; inputs (resources), outputs (activities and participation), and outcomes (intended results). Each component is represented by a list of criteria. Inputs represent the investments in the R&D partnership. For example, the university inputs can be human resources, equipment and facilities, time, and research accomplishments (Behrens et al 2015). Outputs (i.e., activities and participation) represent the different activities done through the R&D partnership, and the people who are reached and impacted by their involvement such as clients, organizations, and decision makers. For example, the activities carried out by university can be doing research in collaborative teams, publishing papers, introducing presentations at conferences (Behrens et al 2015). Also, the participation in the partnership is represented by university (i.e., university research team), industry (i.e., industrial partners), and government (i.e., funding agency). Outcomes represent the intended results of the activities and the expected changes to partnership participants. For example, short-term outcomes represent development in knowledge, skills, attitude, motivation, and awareness (University of Wisconsin-Extension (UWEX) 2003). In addition, medium-term outcomes represent development in behaviours, practices, decisions, actions, strategies, and policies (UWEX 2003). Also, long-term outcomes represent the positive impact on social conditions, economic conditions, political conditions, scientific conditions, and environmental conditions (UWEX 2003). Taylor-Powell et al. (1998) stated that it is important to involve different partnership participants with different backgrounds in identifying the different input, output, and outcomes criteria of the partnership. This helps in integrating different perspectives and having a complete set of criteria to be used in the evaluation process.

3.3 Proposed Generic Logic Model for Evaluating R&D Partnerships in General

The structure of the proposed generic logic model is following the one proposed in the literature by UWEX and University of Idaho-Extension (UIEX) (Taylor-Powell and Henert 2008; McCawley 2001), because it helps in identifying the indicators (i.e., metrics) easily by using the activities' products as indicators in the evaluation process. Consequently, this provides the evaluators with information which helps them to clearly evaluate the partnership and answer the evaluation questions objectively. Another reason is that this structure of logic model clearly states the people who are reached and impacted as a result of their involvement in the partnership. This structure of the logic model describes the different components of the developed logic model as follows: inputs (resources), outputs (activities and participants), outcomes (short-term, medium-term, and long-term "impact"). In addition, the logic model's flowchart format proposed by UWEX (2003) has been applied to format the proposed logic model in this study as shown below in Figure 3.1, Figure 3.2, and Figure 3.3. This format is chosen because the flow chart format visualizes the qualitative relationships and the interdependencies among the partnership's components. The proposed generic logic model is divided on three figures to include the role of university, industry, and government in the partnership in details. This generic logic model is designed to suit the context of R&D partnerships (in general) within or outside Canada.

The criteria of partnership's components have been identified to suit the context of R&D partnership between university, industry, and government. The criteria for inputs, outputs, and outcomes of the three collaborating parties are identified based on the reviewed literature of R&D partnerships and different logic models of several R&D partnerships. In addition, some criteria have been proposed by the researchers of this study, which suit the definition of inputs, outputs, and outcomes of R&D partnerships, based on their understanding of R&D collaborations between university, industry, and government.

3.3.1 The Criteria Used in Representing the Role of University in R&D Partnerships

First, university inputs are the investments in the R&D partnership, such as funds, people, time, skills, and experience. The following list includes university-specific investments (i.e., inputs) in the R&D partnership: qualified research team involved in R&D projects (American Evaluation Association (AEA) 2015; Behrens et al. 2015; Jordan 2015); laboratories and facilities involved in R&D projects (AEA 2015; Behrens et al. 2015; UWEX 2003; McCawley 2001; Jordan 2015); funding (AEA 2015; McCawley 2001; UWEX 2003, Jordan 2015); trust in industrial partners working on R&D projects; time spent on R&D projects (McCawley 2001; UWEX 2003); previous R&D achievements (Jordan 2015; Behrens et al. 2015); industry connections facilitated by R&D collaborations (Behrens et al. 2015; UWEX 2003); and teamwork effectiveness in R&D collaborations.

Second, university outputs are the activities carried out through the R&D partnership, and the people who are reached and impacted by their involvement in the partnership such as clients, organizations, and decision makers. The following list includes university-specific activities carried out through the R&D partnership: doing research in collaborative R&D teams (AEA 2015; Behrens et al. 2015, Jordan 2015); developing tools and solutions to problems through R&D projects (UWEX 2003; Jordan 2015); training industry professionals to enhance their performance and knowledge (AEA 2015; Fielden et al. 2007); publishing papers, technical reports, and newsletters (AEA 2015; McCawley 2001; Jordan 2015); introducing presentations and posters at conferences and seminars; communicating R&D progress and results through the university research team's website; and organizing workshops to present the results of R&D projects (McCawley 2001; Jordan 2015; Remtulla et al. 2014). On the other hand, the parties reached and impacted by the R&D partnership are as follows: university (i.e., research team), industry (i.e., industrial partners), and government (i.e., funding agency).

Third, university short-term outcomes are the outcomes that result directly from the outputs; they include changes in awareness, knowledge, skills, attitudes, and aspirations. The university short-term outcomes are defined as following: graduating highly experienced personnel (Behrens et al. 2015); linking scientific theories with practical applications; improving the reputation of researchers among their peers (Behrens et al. 2015); increasing the knowledge of researchers (AEA 2015; Behrens et al. 2015; Fielden et al. 2007; McCawley 2001); fostering improved collaboration and stable relationships with industry (AEA 2015; Jordan 2015; Behrens et al. 2015, Remtulla et al. 2014); and better understanding of industry needs (AEA 2015; Behrens et al. 2015).

Fourth, university medium-term outcomes are the outcomes that result from the application of short-term outcomes; they include changes in reputations, practices, actions, management strategies, and decisions. The university medium-term outcomes are defined as follows: satisfying industry needs (AEA 2015); enhanced academic reputation of the department and/or university (Behrens et al. 2015); expansion of the research program (Behrens et al. 2015); employment of highly qualified personnel (HQP) (Behrens et al. 2015; Remtulla et al. 2014); enhanced feedback mechanisms for better communication and collaboration with industry (Behrens et al. 2015); creation of innovative technologies (AEA 2015); and enhancement of the management system for R&D projects.

Fifth, university long-term outcomes are the outcomes that result from the application of medium-term outcomes; they include changes in scientific conditions, economic conditions, and environmental conditions. The criteria for university medium-term outcomes are defined as follows: maintaining a leading position among top-ranked research universities all over the world; development of nationally and internationally-recognized expertise in various research areas (Behrens et al. 2015); contributing to improved environmental conditions for citizens (AEA 2015; UWEX 2003; McCawley 2001); enhancing the global competitiveness of the country's economy (AEA 2015; UWEX 2003; McCawley 2001; Behrens et al. 2015; Remtulla et al. 2014; Jordan 2015); and enhancing the country's level of technological innovation on a global scale (Behrens et al. 2015).

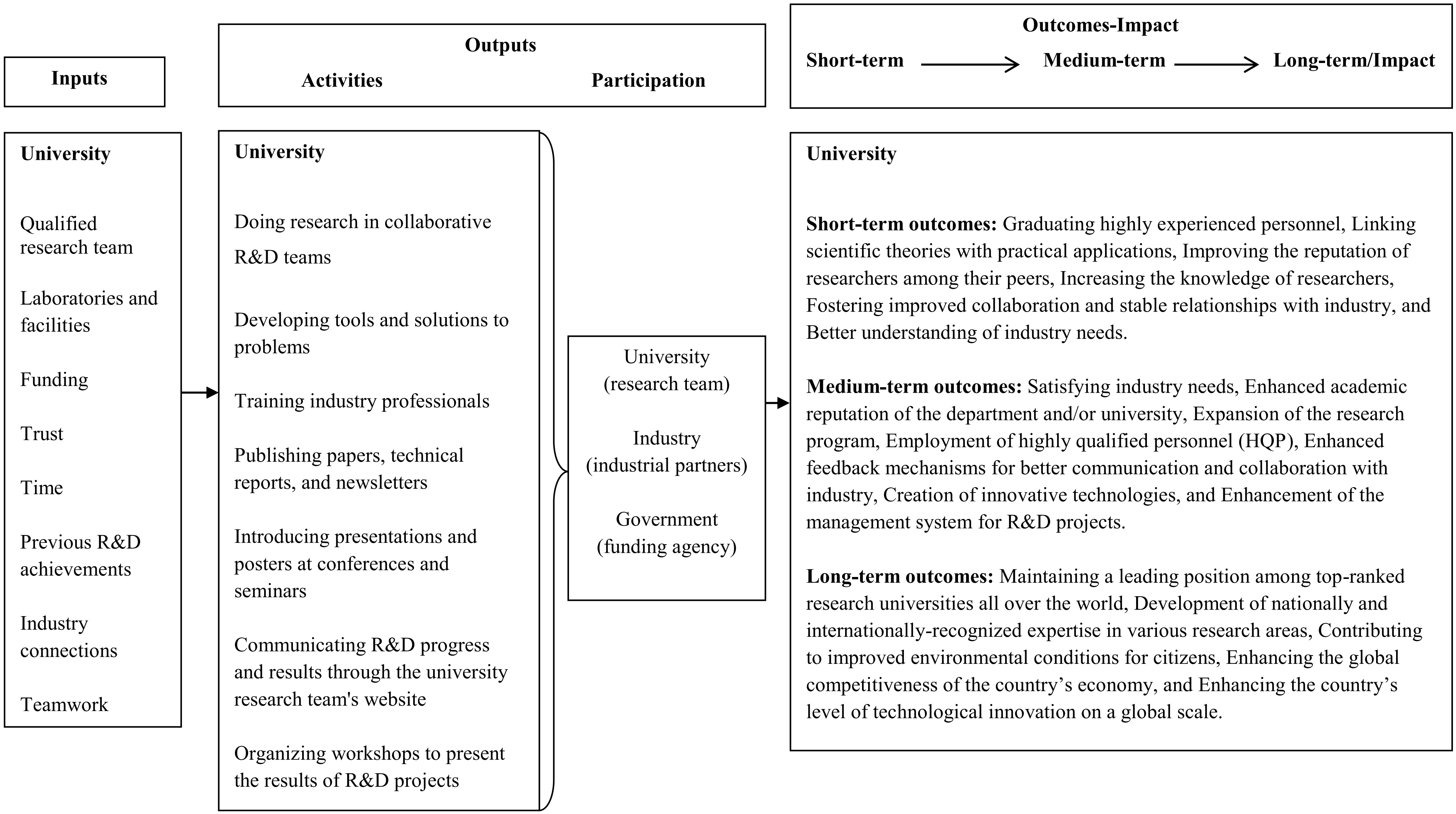

Figure 3.1. Proposed generic logic model with a focus on university's role in R&D partnerships

3.3.2 The Criteria Used in Representing the Role of Industry in R&D Partnerships

First, industry inputs are the investments in the R&D partnership, such as funds, people, time, skills, and experience. The following list includes industry-specific investments (i.e., inputs) in the R&D partnership: organizational funding for R&D projects (AEA 2015; Behrens et al. 2015; Jordan 2015; McCawley 2001); in-kind contributions (materials, equipment, time spent by organizational personnel on projects, etc.) supplied by the organization to the university (AEA 2015; Behrens et al. 2015; UWEX 2003; McCawley 2001; Jordan 2015); qualified industry professionals involved in R&D projects (AEA 2015; Behrens et al. 2015; Jordan 2015); time spent on R&D projects (UWEX 2003; Behrens et al. 2015; McCawley 2001); previous successful collaborative R&D projects (Behrens et al. 2015); trust in academic partners working on R&D projects; teamwork effectiveness in R&D collaborations; access to technical data provided to the university research team (Behrens et al. 2015); and university connections facilitated by R&D collaborations (UWEX 2003).

Second, industry outputs are the activities carried out through the R&D partnership and the people who are reached and impacted by their involvement in the R&D partnership such as clients, organizations, and decision makers. The following list includes industry-specific activities carried out through the R&D partnership: working with university in the execution of R&D projects (AEA 2015; Behrens et al. 2015, Jordan 2015); assisting the university in the development of tools to address market needs (UWEX 2003; Jordan 2015); providing industry training to students by offering internships at the organization (AEA 2015; Fielden et al. 2007; Jordan 2015); providing technical support to the university research team on R&D projects (Behrens et al. 2015); and using university facilities and laboratories for the purpose of R&D projects. On the other hand, the parties reached and impacted by the R&D partnership are as follows: university (i.e., research team), industry (i.e., industrial partners), and government (i.e., funding agency).

Third, industry short-term outcomes are the outcomes that result directly from the outputs; they include changes in attitudes, awareness, knowledge, skills, and aspirations. The industry short-term outcomes are defined as follows: fostering improved collaboration with the university on R&D projects (Behrens et al. 2015; Fielden et al. 2007; AEA 2015; Remtulla et al. 2014); increasing the experience of employees (AEA 2015; Jordan 2015); increasing the knowledge of employees (AEA 2015; Fielden et al. 2007); improving the organization's national competitive position among other organizations (AEA 2015; Jordan 2015); and better understanding of market needs (Jordan 2015).

Fourth, industry medium-term outcomes are the outcomes that result from the application of short-term outcomes; they include changes in practices, actions, management strategies, and decisions. The industry medium-term outcomes are defined as follows: hiring highly qualified personnel (HQP) to work at the organization (Jordan 2015; Behrens et al. 2015; Remtulla et al. 2014); enhanced feedback mechanisms for better communication and collaboration with the university on R&D projects (Behrens et al. 2015); changes in the organization's practices and strategies leading to improved industry performance (Jordan 2015; Behrens et al. 2015; AEA 2015); enhanced management system for construction projects (Jordan 2015; Behrens et al. 2015); and sharing in the ownership of innovative results and products developed through R&D partnerships (Jordan 2015; Behrens et al. 2015; AEA 2015).

Fifth, industry long-term outcomes are the outcomes that result from the application of medium-term outcomes; they include changes in economic conditions, environmental conditions, and scientific conditions. The industry long-term outcomes are defined as follows: higher profits for the organization and better project and organizational performance (AEA 2015; Jordan 2015); increased competitive standing of the organization in international markets (Jordan 2015; Behrens et al. 2015; Remtulla et al. 2014); contributing to improved economic conditions the country (AEA 2015; UWEX 2003; McCawley 2001; Behrens et al. 2015; Remtulla et al. 2014; Jordan 2015); contributing to improved environmental conditions for citizens (AEA 2015; UWEX 2003; McCawley 2001); and enhancing the organization’s level of innovation (Behrens et al. 2015).

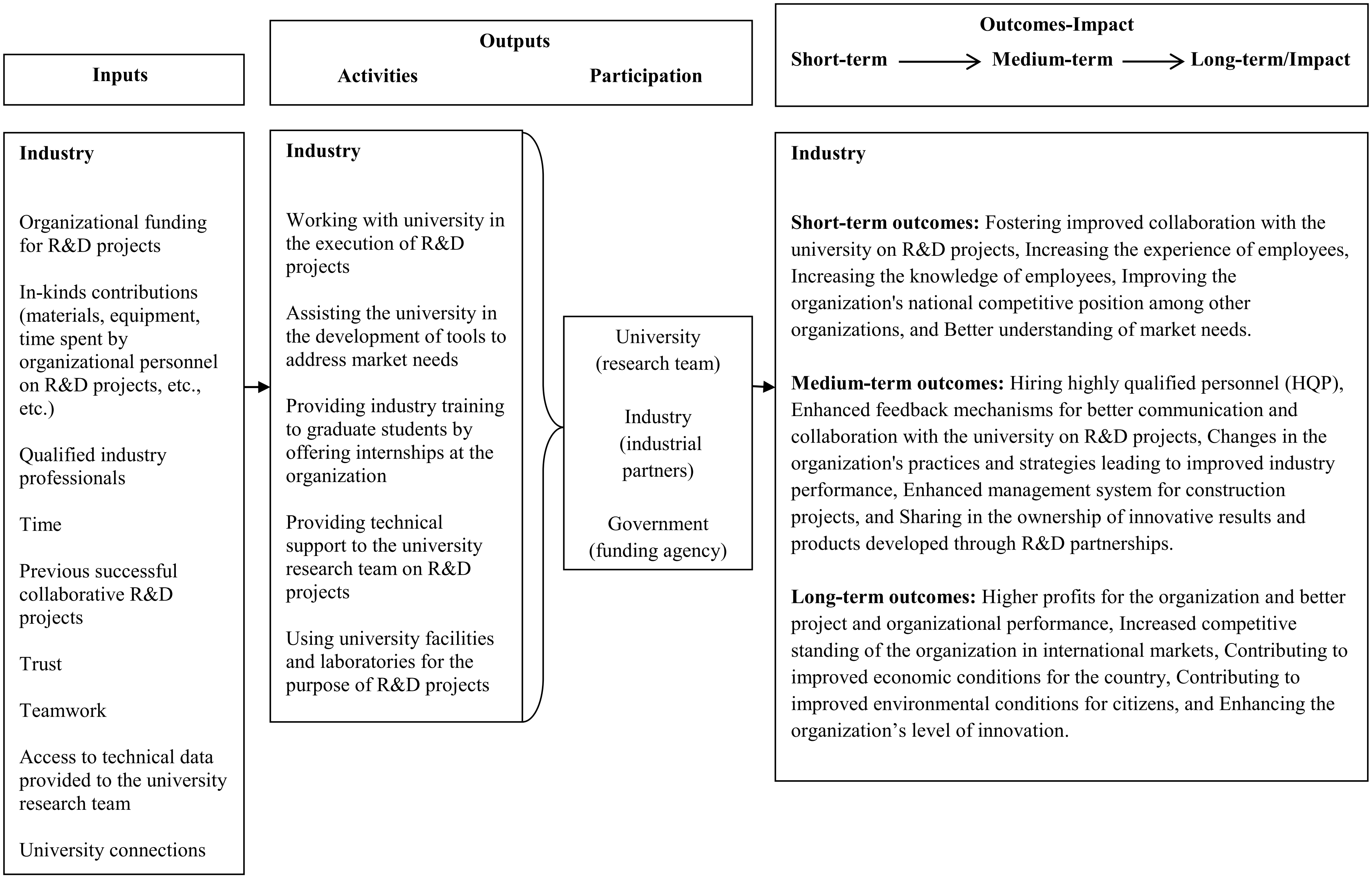

Figure 3.2. Proposed generic logic model with a focus on industry's role in R&D partnerships

3.3.3 The Criteria Used in Representing the Role of Government in R&D Partnerships

First, government inputs are the investments in the R&D program, such as funds, people, time, skills, and experience. The following list includes investments (i.e., inputs) that are specific to government in the R&D partnership: qualified personnel involved in R&D partnerships (NRC 2009); funds (Behrens et al. 2015; NRC 2009); facilities supplied by the organization to R&D teams (Jordan 2015); time spent on R&D projects (NRC 2009); previous R&D achievements (Jordan 2015); existing management tools and systems; existing partnerships (Jordan 2015), knowledge of market and government needs (Jordan 2015).

Second, government outputs are the activities carried out through the R&D partnership, and the people who are reached and impacted by their involvement such as clients, organizations, and decision makers. The following list includes activities carried out by government through the R&D partnership: working with university and industry on R&D projects (Jordan 2015; NRC 2009; Behrens et al. 2015); attracting highly qualified personnel (HQP) to work on different R&D projects (NRC 2009; Behrens et al. 2015); providing technical support to R&D teams (Jordan 2015); setting funding polices and guidelines (Tremblay et al. 2010; NRC 2009); setting research roadmaps and strategies (Tremblay et al. 2010; NRC 2009); publishing of communication materials (i.e., guides, reports, announcements, etc.) (Tremblay et al. 2010; NRC 2009); reviewing and selecting applications for funds (Tremblay et al. 2010; Behrens et al. 2015); assigning funds to R&D projects (Tremblay et al. 2010; Behrens et al. 2015); monitoring of assigned funds (Tremblay et al. 2010; Behrens et al. 2015); and providing training workshops for university and industry (NRC 2009). On the other hand, the parties reached and impacted by the R&D partnership are as follows: university (i.e., the university research team), industry (i.e., industrial partners), and government (i.e., funding agency).

Third, government short-term outcomes are the outcomes that result directly from the outputs; they include changes in aspirations, knowledge, skills, attitudes, and awareness. The government short-term outcomes are defined as follows: enhanced collaboration between university and industry (NRC 2009; AEA 2015); increased number of highly qualified personnel (HQP) supplied from the university (NRC 2009; AEA 2015); improved access to technology knowledge and information transfer tool (NRC 2009; AEA 2015); improved use of technology (Jordan 2015; NRC 2009; AEA 2015); and development of advanced solutions that address market needs and priorities (Jordan 2015; NRC 2009).

Fourth, government medium-term outcomes are the outcomes that result from the application of short-term outcomes; they include changes in actions, management strategies, practices, and decisions. The criteria for government medium-term outcomes are defined as follows: increased investment of funds by industry in R&D projects (NRC 2009); diffusion of knowledge and technology to companies and government (AEA 2015; Jordan 2015); employment of highly qualified personnel (HQP) in areas that serve the industrial development (NRC 2009); and commercial development by introducing new products and services to the market (Jordan 2015; NRC 2009).

Fifth, government long-term outcomes are the outcomes that result from the application of medium-term outcomes; they include changes in economic conditions, social conditions, scientific conditions, and environmental conditions. The criteria for government long-term outcomes are defined as follows: international recognition among world countries (Tremblay et al. 2010; NRC 2009); stronger economy by having competitive industries (Tremblay et al. 2010; Jordan 2015; AEA 2015); enhanced annual income and economic benefits for citizens (NRC 2009; Tremblay et al. 2010); introducing and exporting highly qualified products and services to worldwide countries (NRC 2009; Jordan 2015); and contributing to improved environmental conditions for citizens (AEA 2015; UWEX 2003; McCawley 2001).

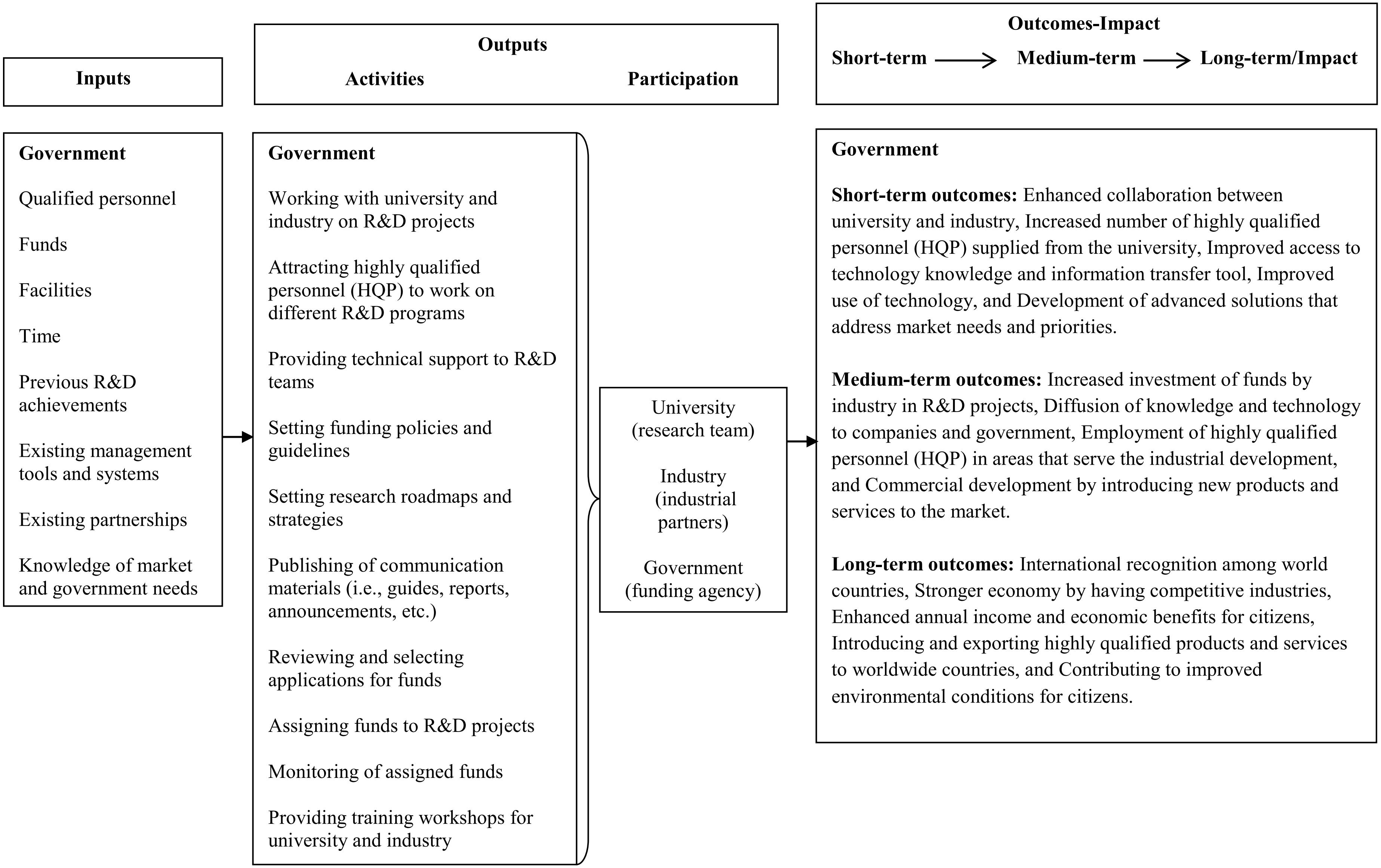

Figure 3.3. Proposed generic logic model with a focus on government's role in R&D partnerships

3.4 Proposed Generic Submodel for Evaluating Different IRCs within the NSERC IRC Program

In this submodel, the roles of university, industry, and government listed in the aforementioned generic logic model are refined ant tailored to suit the role played by these three collaborating parties in R&D partnerships within the IRC program. NSERC plays an important role in R&D enhancement in Canada (NSERC 2011). The main goal of NSERC is to "provide Canadians with economic and social benefits arising from the provision of a highly skilled workforce, knowledge transfer of Canadian discoveries in the natural sciences and engineering from universities and colleges to other sectors, and informed access to research results from around the world." (Goss Gilroy Inc. (GG) 2006). The Research Partnership Program (RPP) is one of the NSERC's directorates (GG 2006). It works on enhancing the research and training, and linking universities with public and private sectors. The RPP delivers its vision through different programs which are categorized into three groups as follows: Innovation Projects, Building Critical Mass Programs, and Technology Transfer. Firstly, the Innovation Projects includes: Strategic Projects, Strategic Networks, Collaborative Research and Development Grants, and Research Partnership Grants. Secondly, the Building Critical Mass Program includes: Industrial Research Chairs, Chairs in Design Engineering, and Chairs for Women in Science and Engineering. Thirdly, the Technology Transfer includes: Idea to Innovation, and Intellectual Property Mobilisation.

The IRC is a part of many programs which belong to the Building Critical Mass programs in the RPP (GG 2006). The IRC was first established in 1983. The first IRC initiated was the NSERC/New Brunswick Power IRC in Nuclear Engineering. Nowadays, more than 300 IRCs have been established since the beginning of the IRC program. The IRC program works on developing a strong relationship between industry and universities. It provides long-term funding to enhance the research collaboration between industry and universities. This collaboration aims to satisfy the industry needs, and solve most of the problems faced by industrial partners. The IRC has three main objectives as follows: 1) helping universities in strengthening current research areas to achieve a breakthrough in science and engineering which the industry seeks; 2) helping the expansion of new research areas which have not been developed before in Canadian universities and which the industry needs; and 3) providing graduate students and postdoctoral fellows with enhanced training by exposing them to interactions with industrial partners and research activities related to industrial problems.

The criteria for the three collaborating parties listed in the proposed generic logic model in the previous section have been tailored and refined to suit the context of the IRC program as shown in Figure 3.4, Figure 3.5, and Figure 3.6. Besides, additional criteria were retrieved from the NSERC IRC program's logic model proposed by GG (2006) and the 48-months evaluation report of the NSERC IRC in Strategic Construction Modeling and Delivery (SCMD). The participation here in the submodel is made specific compared to the proposed generic model as follows: the participation of university is represented by the chairholder of IRC and his/her research team members; the participation of the industry is represented by the partners of the IRC and industry at large; and the participation of the government is represented by NSERC.

According to Canadian Academy of Health Sciences (CAHS) (2009) outcomes can be mapped into the following main themes or categories: capacity building; advancing knowledge; informing decision making; health impacts; and social and economic impacts. However, health impacts category was excluded from the main impact categories in this study as it is not relevant to the construction context. Capacity building outcomes category represents the development in personnel, funding of research, and infrastructure. Advancing knowledge outcomes category represents the development in the research quality, collaborations and partnerships, and research activities. Informing decision making outcomes category represents the development in policies and practices, and software and research products. Social and economic impacts category represents the development in well-being, spin outs, and intellectual property and licensing resulting from research activities. Based on that, the different parties' outcomes in construction R&D partnerships are classified as shown in Table 3.1, Table 3.2, and Table 3.3.

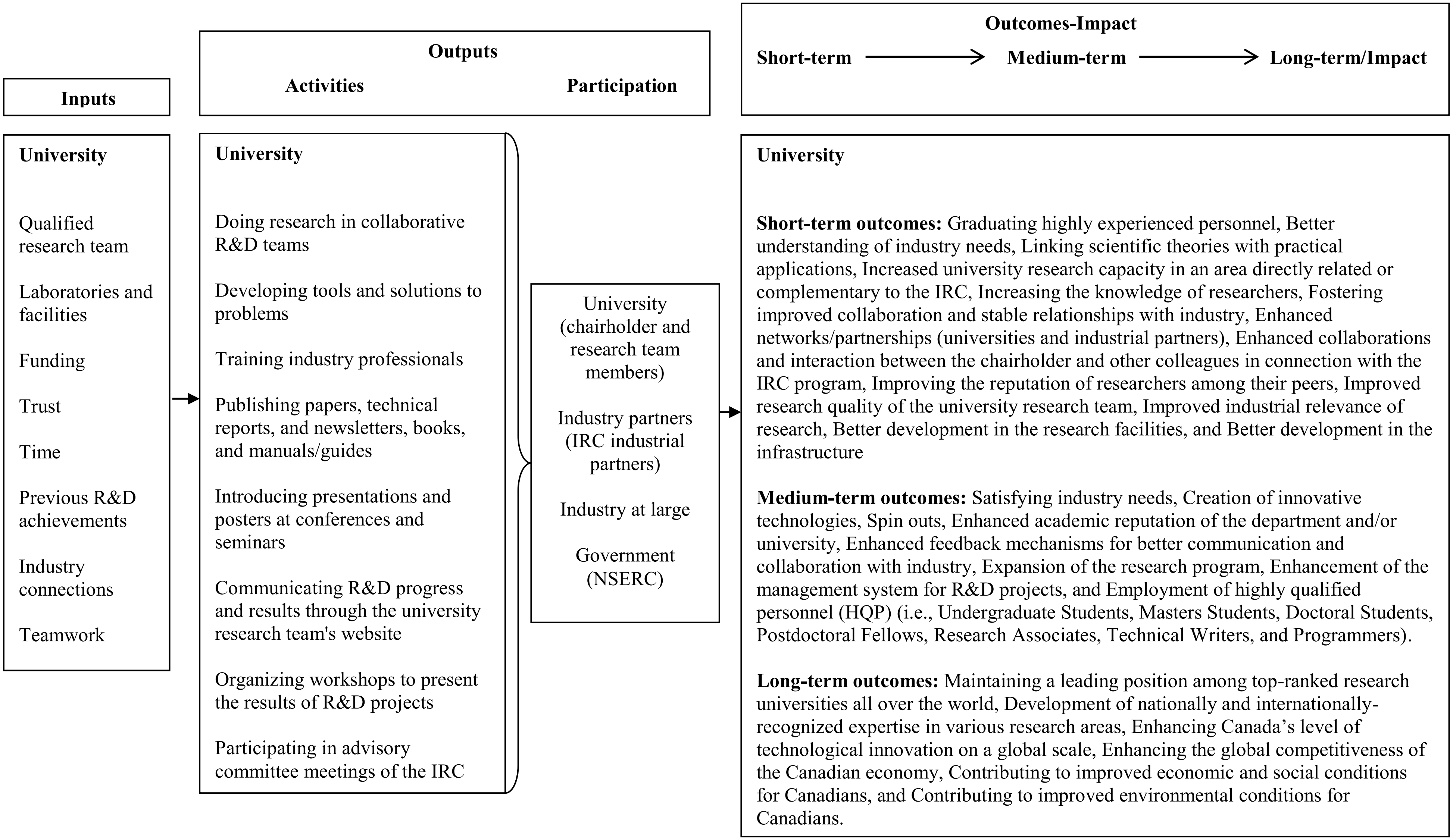

Figure 3.4. Proposed generic submodel with a focus on the role of university in R&D partnerships within the NSERC IRC program

Table 3.1. Classification of university outcomes criteria into main impact categories

Capacity building	**Advancing Knowledge**	**Informing Decision Making**	**Social and Economic Impacts**
• Graduating highly experienced personnel	• Better understanding of industry needs • Increased university research capacity in an area directly related or complementary to the IRC	• Linking scientific theories with practical applications	• Spin outs
• Increasing the knowledge of researchers • Improving the reputation of researchers among their peers • Better development in the research facilities	• Fostering improved collaboration and stable relationships with industry • Enhanced networks/partnerships (universities and industrial partners) • Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	• Satisfying industry needs • Creation of innovative technologies • Enhanced feedback mechanisms for better communication and collaboration with industry	• Employment of highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) • Enhancing Canada's level of technological innovation on a global scale
• Better development in the infrastructure	• Improved research quality of the university research team • Improved industrial relevance of research • Enhanced academic reputation of the department and/or university • Expansion of the research program • Maintaining a leading position among top-ranked research universities all over the world • Development of nationally and internationally-recognized expertise in various research areas	• Enhancement of the management system for R&D projects	• Enhancing the global competitiveness of the Canadian economy • Contributing to improved economic and social conditions for Canadians • Contributing to improved environmental conditions for Canadians

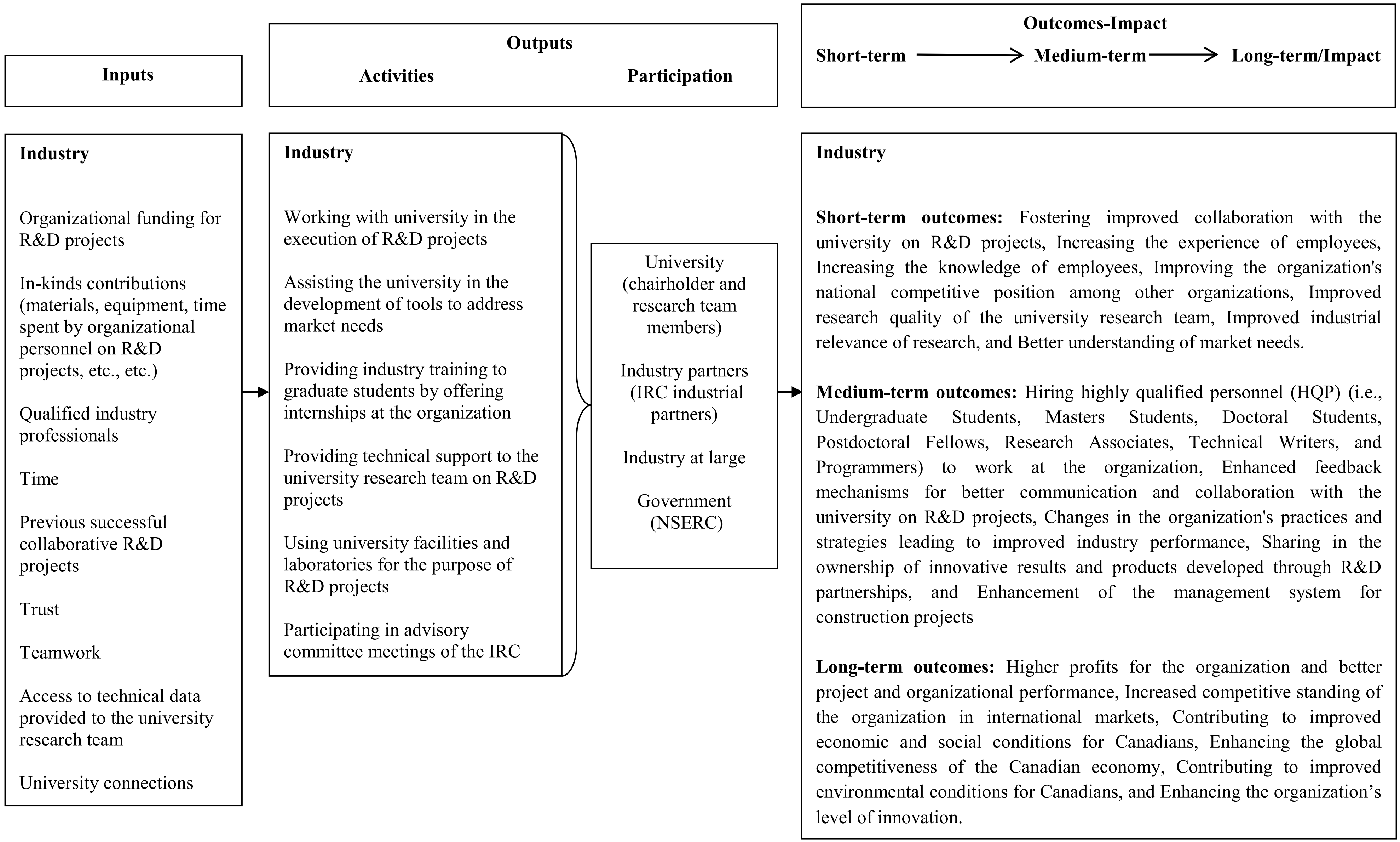

Figure 3.5. Proposed generic submodel with a focus on the role of industry partners in R&D partnerships within the NSERC IRC program

Table 3.2. Classification of construction industry partners outcomes criteria into main impact categories

Capacity building	Advancing Knowledge	Informing Decision Making	Social and Economic Impacts
• Increasing the experience of employees • Increasing the knowledge of employees	• Better understanding of market needs • Fostering improved collaboration with the university on R&D projects • Improved research quality of the university research team • Improved industrial relevance of research • Enhancing the organization’s level of innovation	• Enhancement of the management system for construction projects • Enhanced feedback mechanisms for better communication and collaboration with the university on R&D projects • Changes in the organization's practices and strategies leading to improved industry performance • Sharing in the ownership of innovative results and products developed through R&D partnerships	• Improving the organization's national competitive position among other organizations • Increased competitive standing of the organization in international markets • Higher profits for the organization and better project and organizational performance • Hiring highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) to work at the organization • Enhancing the global competitiveness of the Canadian economy • Contributing to improved economic and social conditions for Canadians • Contributing to improved environmental conditions for Canadians

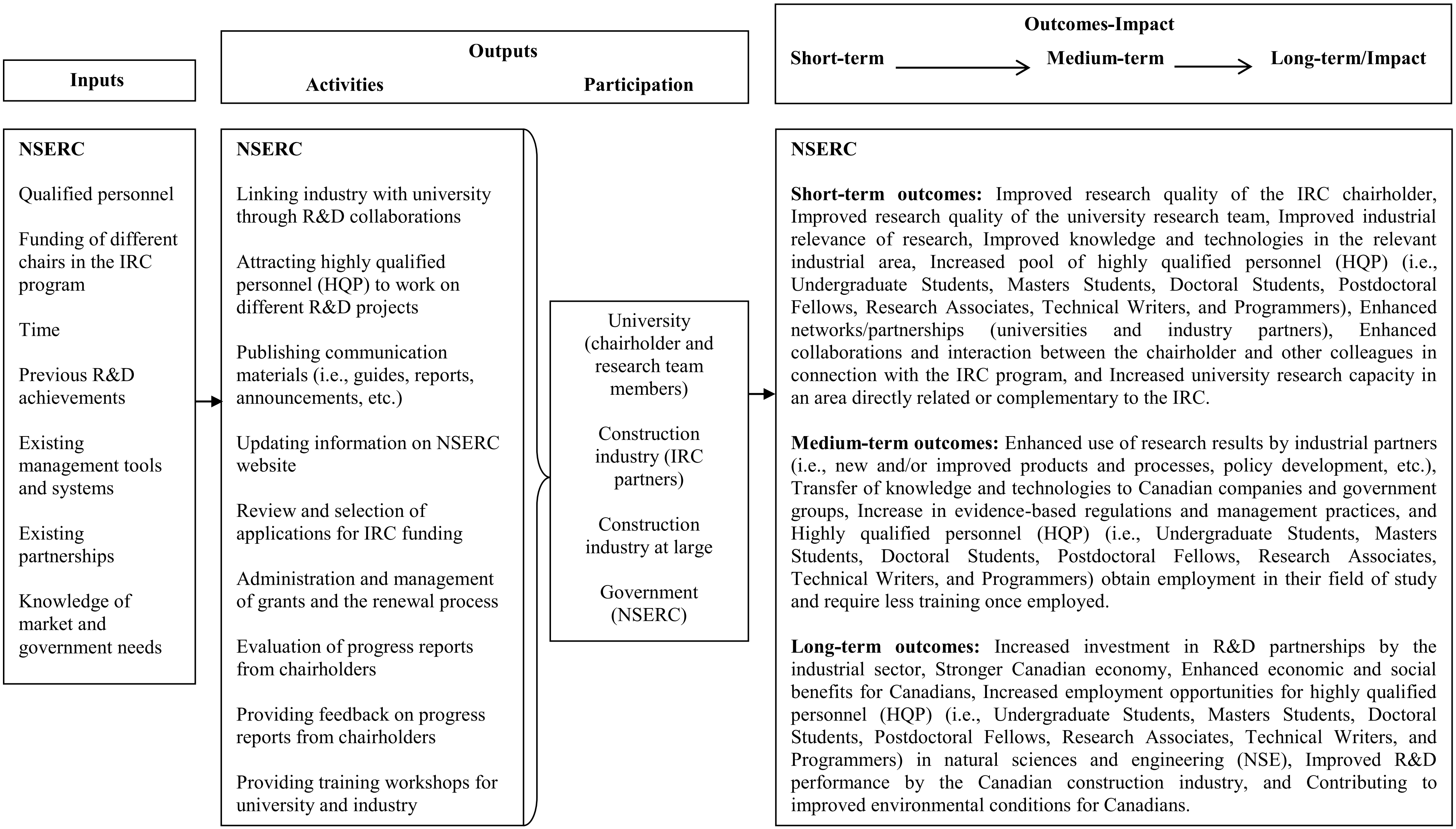

Figure 3.6. Proposed generic submodel with a focus on the role of NSERC in R&D partnerships within the NSERC IRC program

Table 3.3. Classification of NSERC outcomes criteria into main impact categories

Capacity building	Advancing Knowledge	Informing Decision Making	Social and Economic Impacts
• Increased pool of highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) with research expertise relevant to the industrial sector • Highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) obtain employment in their field of study and require less training once employed • Increased investment in R&D partnerships by the industrial sector	• Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program • Increased university research capacity in an area directly related or complementary to the IRC • Enhanced networks/partnerships (universities and industrial partners) • Enhanced networks/partnerships (universities and industry partners) • Improved R&D performance by the Canadian construction industry • Improved research quality of the IRC chairholder • Improved research quality of the university research team • Improved industrial relevance of research	• Enhanced use of research results by industrial partners (i.e., new and/or improved products and processes, policy development, etc.) • Transfer of knowledge and technologies to Canadian companies and government groups • Increase in evidence-based regulations and management practices	• Stronger Canadian economy • Enhanced economic and social benefits for Canadians • Increased employment opportunities for highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) in natural sciences and engineering (NSE) • Contributing to improved environmental conditions for Canadians

3.5 Metrics and Scales for Different Criteria for Inputs, Outputs, and Outcomes

Metrics and indicators are the same, in which the two terms are used interchangeably in the literature. Different metrics and corresponding scales have to be assigned to the different criteria included in the logic model to evaluate them. The metrics (i.e., indicators) are the evidence or information used to measure and evaluate the criteria and define the data that will be collected for evaluation (UWEX 2003). These metrics are defined to suit the context of the R&D program, and to reflect the perspectives of the partners and the expected outcomes of the program (Taylor-Powell et al. 1996). Hauser and Zettelmeyer (1996) stated some metrics used in the evaluation of research, development, and engineering (R, D &E) projects. The metrics let the evaluators know whether the outcomes have been achieved or not and to which degree of fulfilment (Taylor-Powell et al. 1998). They help to answer the evaluation questions; they provide the evaluator with the data needed to evaluate the program performance. These metrics can be qualitative or quantitative. Examples of qualitative metrics were mentioned by Hauser and Zettelmeyer (1996) to be used in the evaluation of (R, D &E) projects such as: scope of the technology, effectiveness of new system, quality of research, quality of the people, and customer satisfaction. On the other hand, quantitative metrics are used in the evaluation of (R, D &E) projects such as: counts of innovation, number of patents, percent of goal achievement, technical specifications fulfillment, time for completion, speed of applying technology into new products, economic value added, and overhead cost of research.

The type of assigned scale depends on the type of the metric whether it is quantitative or qualitative. For example, Omar and Fayek (2014) used numerical scales (e.g., numerical values and percentages) to measure quantitative performance indicators (metrics), and rating scales to measure qualitative performance indicators. Marsh and Fayek (2010) used a predetermined rating scale which consists of 7 point ratings to measure variables that are difficult to be quantified using numerical values. The predetermined rating scales helps in reducing the subjectivity related to judgment of experts on subjective criteria (Marsh and Fayek 2010). The difference between rating scales and predetermined rating scales is that the latter combines multiple factors, stated at different levels, for each rating point. Rea and Parker (1997) defined different measurement scales which can be used to measure qualitative and quantitative metrics. Nominal scale and ordinal scale can be used to measure qualitative metrics. Interval scale (i.e., numerical values) can be used to measure quantitative metrics.

First, the nominal scale is used to identify the observations related to the survey data. The survey data are categorized and defined by frequency of occurrence. No ranking or estimation is applied to the data categories. For example, the responses to a survey question about political party preference can be categorized into three main categories which are: republican, democrat, and independent. As we can see, the different categories are not ranked. In addition, no value is available to express the degree of preference of the political party. Second, the ordinal scale focuses on ranking the data categories in terms of the extent to which they have the properties of the variable (metric). It gives information about the categories' orders but no indication about the difference in magnitude among these categories. In other words, it provides ranking among categories but no estimation. For example, asking about the highest academic degree received in education, we can find the data can be categorized as doctoral, master's, and bachelor degrees. There is obvious ranking of categories from highest to lowest but no values for categories present which can show the difference in magnitude between these categories. To solve that problem, scaled responses can be used to give a value (rating) for each category among the responses. A Likert scale (i.e., rating scale) which is composed of five-, seven-, or nine- point ratings can be used to measure the respondent's attitude on a continuum from highly favourable to highly unfavourable. The number of positive and negative ratings has to be equal with one middle or neutral rating. The Likert scale is suitable in the context of collecting attitudinal information about subjective matter. Vagias (2006) stated different types of Likert type scale responses which can be used to address different attitudes such as: acceptability, agreement, and satisfaction. Third, the interval scale is used to collect the largest amount of information about the variable (metric). "It labels, orders, and uses constant units of measurement to indicate the exact value of each category of response" (Rea and Parker 1997). For example, variables (metrics) such as income, height, and age are measured using accurate indications of values for each category which express the differences among different categories.

Several studies have been reviewed to develop different metrics used in evaluating the criteria listed in the proposed submodel (Jyoti et al. 2006; Samsonowa et al. 2009; Chiesa et al. 2008; Choi and Ko 2010; Ojanen and Vuola 2003; Sawang 2011; Agostino et al. 2012; Elbarkouky et al. 2014; Hanel and St-Pierre 2006; Holi et al. 2008; NSERC 2009; Paine 2003; Park et al. 2013; Schwartz et al. 2011; University of Victoria (UVic) 2011; Weisbrod and Weisbrod 1997). Besides, some metrics have been developed by the researchers of this study based on the 48-months evaluation report of the NSERC IRC in SCMD and their understanding of the R&D collaborations within NSERC IRC in SCMD. All the criteria, corresponding metrics, and scales are tabulated in Appendix A in details. Examples of criteria, corresponding metrics, and scales used for evaluating inputs, outputs, and outcomes of different collaborating parties are tabulated below in Table 3.4, Table 3.5, and Table 3.6 respectively, in order to give an idea about the criteria, metrics, and scales used in this study to evaluate the NSERC IRC. After investigating the different types of scales in this section, different scales are developed to measure the corresponding qualitative and quantitative metrics. Numerical scales (i.e., numerical values and percentages) are used in this study to measure different quantitative metrics in the proposed submodel. In addition, Likert scales (i.e., rating scales) are used to measure the attitudes and opinions towards qualitative metrics such as level of agreement or disagreement. Different Likert scales defined by Vagias (2006) are used to suit the addressed qualitative metrics in the proposed submodel. Also, other rating scales are developed to suit the context of the metrics. In addition, few nominal scales have been used to evaluate some qualitative criteria.

For example, in evaluating the NSERC IRC in SCMD as investigated later in chapter 4, the input criterion of university named "previous R&D achievements" is evaluated using two quantitative metrics as follows: (1) number of R&D projects with industry participants of the IRC completed on time and on budget; and (2) total number of R&D projects with industry participants of the IRC. The two metrics are measured using numerical values to indicate the number of R&D projects completed on time and within budget, and total number of R&D projects with industry partners. Also, the input criterion of construction industry named "organizational funding for R&D projects" is evaluated using a quantitative metric which is total amount of Canadian dollars invested in R&D projects within the IRC. This metric is measured using numerical values to indicate the amount of funds invested by the industry in R&D

collaborations with university within the IRC. In addition, the input criterion of NSERC named "knowledge of market and government needs" is evaluated using a qualitative metric which is the level of awareness of the IRC towards the market and government needs. This metric is measured using Likert scale named "level of awareness" which consists of five points as follows: not aware at all, slightly aware, somewhat aware, very aware, and extremely aware. This scale is used to indicate the awareness and knowledge of the IRC towards the market and government needs.

However, in developing the proposed submodel, it is found that some criteria can be measured using both quantitative and qualitative metrics. For example, the input criterion of university named "laboratories and facilities involved in R&D projects" is evaluated using a quantitative metric which is number of laboratories and/or research spaces involved in R&D projects within the IRC, and a qualitative metric which is quality of laboratories and/or research spaces used in R&D projects within the IRC. The quantitative metric is measured by numerical values to indicate the number of laboratories and facilities used in R&D projects. On the other hand, the qualitative metric is measured using Likert scale named "level of quality" which consists of five points as follows: poor, fair, good, very good, and excellent. This scale is used to indicate the quality of laboratories and facilities used in R&D projects.

Also, the output criterion of construction industry named "working with university in the execution of R&D projects" is evaluated using two quantitative metrics and two qualitative metrics. The quantitative metrics are as follows: (1) number of basic, applied, and basic and applied R&D projects carried out within the IRC; and (2) number of graduate students posted at the organization and/or job sites within the IRC. The two qualitative metrics are as follows: (1) frequency of working with university in the execution of R&D projects within the IRC; and (2) level of satisfaction with the collaboration with university on R&D projects within the IRC. The quantitative metrics are measured by numerical values to indicate the number of R&D projects which the industry is involved in with university, and the number of graduate students posted at the organizations of the industrial partners of the IRC through R&D projects. On the other hand, the qualitative metric, named frequency of working with university in the execution of R&D projects within IRC in SCMD, is measured using Likert scale named "frequency" which consists of five points as follows: never, rarely, sometimes, often, and usually. This scale is used to show

how frequent the industry is working with university on R&D projects. The other qualitative metric, which is named level of satisfaction with the collaboration with university on R&D projects within IRC in SCMD, is measured using Likert scale named “level of satisfaction” which consists of five points as follows: very dissatisfied, dissatisfied, unsure, satisfied, and very satisfied. This scale is used to express the extent of industry satisfaction from working with university on R&D projects.

Table 3.4. Examples of inputs criteria and corresponding metrics of different parties

Participant	Input criterion	Metric	Scale
University	Previous R&D achievements	• Number of R&D projects with industry participants of the IRC completed on time and on budget • Total number of R&D projects with industry participants of the IRC	Numerical values Numerical values
	Industry connections facilitated by R&D collaborations	• Number of R&D industrial partners of the IRC	Numerical values
	Laboratories and facilities involved in R&D projects	• Number of laboratories and/or research spaces involved in R&D projects within the IRC • Quality of laboratories and/or research spaces used in R&D projects within the IRC	Numerical values 1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Excellent
Construction Industry	Organizational funding for R&D projects	• Total amount of Canadian dollars invested in R&D projects within the IRC	Numerical values
	Time spent on R&D projects	• Number of hours spent monthly on R&D projects within the IRC	Numerical values
	In-kind contributions supplied by the organization to the university	• Expenditures on in-kind contributions (materials, equipment, time of technicians, etc.) supplied by the organization to university for R&D projects within the IRC	Numerical values
NSERC	Knowledge of market and government needs	• Level of awareness of the IRC towards the market and government needs	1-Not aware at all, 2-Slightly aware, 3-Somewhat aware, 4-Very aware, 5-Extremely aware

Table 3.5. Examples of outputs criteria and corresponding metrics of different parties

Participant	Output criterion	Metric	Scale
University	Developing tools and solutions to problems through R&D projects	• Frequency of implementing tools and solutions developed through R&D projects by the industrial partners of the IRC	1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Usually
		• Number of software applications developed through R&D projects within the IRC	Numerical values
		• Level of quality of R&D projects results within the IRC	1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Excellent
Construction Industry	Working with university in the execution of R&D projects	• Frequency of working with university in the execution of R&D projects within the IRC	1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Usually
		• Number of basic, applied, and basic and applied R&D projects carried out within the IRC	Numerical values
		• Level of satisfaction with the collaboration with university on R&D projects within the IRC	1-Very dissatisfied, 2-Dissatisfied, 3-Unsure, 4-Satisfied, 5-Very satisfied
		• Number of graduate students posted at the organization and/or job sites within the IRC	Numerical values
NSERC	Publishing of communication materials (i.e., guides, reports, announcements, etc.)	• Frequency of publishing communication materials (i.e., guides, reports, announcements, etc.)	Numerical values
		• Level of quality of publications	1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Excellent
	Providing training workshops for university and industry groups	• Number of training workshops carried out for partners of the IRC	Numerical values
		• Number of personnel trained per training workshop provided to partners of the IRC	Numerical values
		• Level of satisfaction with the outcomes of the training provided to partners of the IRC	1-Very dissatisfied, 2-Dissatisfied, 3-Unsure, 4-Satisfied, 5-Very satisfied

Table 3.6. Examples of outcomes criteria and corresponding metrics of different parties

Participant	Class of outcomes	Outcome criterion	Metric	Scale
University	***Short-term outcomes***	Graduating highly experienced personnel	• Level of increase in the experience of the university research team by participating in R&D projects within the IRC	1-Very low, 2-Low. 3-Medium,4-High, 5-Very high
	Medium-term outcomes	Satisfying industry needs	• Level of satisfaction of industry needs by the results of R&D projects carried out through the IRC	1-Very dissatisfied, 2-Dissatisfied, 3-Unsure, 4-Satisfied, 5-Very satisfied
	Long-term outcomes	Maintaining a leading position among top-ranked research universities all over the world	• Rank of Faculty of Engineering at the university	Numerical values
Construction industry	***Short-term outcomes***	Improving the organization's national competitive position among other organizations	• The annual percentage improvement of the organization's share in the domestic market after being involved in R&D projects within the IRC	Percentage
	Medium-term outcomes	Enhancement of the management system for construction projects	• Level of enhancement in the quality of management system for the construction projects by working with the university research team for the IRC on different R&D projects	1-Not enhanced at all, 2-Slightly enhanced, 3-Somewhat enhanced, 4-Very enhanced, 5-Extremely enhanced
	Long-term outcomes	Increased competitive standing of the organization in international markets	• The annual percentage improvement of the organization's share in the international market after being involved in R&D projects within the IRC	Percentage
NSERC	***Short-term outcomes***	Increased pool of highly qualified personnel (HQP) with research expertise relevant to the industrial sector	• Level of increase of the HQP number in the construction domain as a result of R&D projects within the IRC	1-Very low, 2-Low, 3-Medium, 4-High, 5-Very high
	Medium-term outcomes	Transfer of knowledge and technologies to Canadian companies and government groups	• Frequency of knowledge and technologies transfer to Canadian organizations and governmental bodies through R&D projects within the IRC	1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Always
	Long-term outcomes	Enhanced economic and social benefits for Canadians	• Level of effect of the IRC on the enhancement of the economic and social conditions for Canadians	1-Not effective at all, 2-Slightly effective, 3-Somewhat effective, 4-Very effective, 5-Extremely effective

3.6 Concluding Remarks

Logic model consists of three components as follows: inputs (i.e., resources), outputs (i.e., activities and participation), and outcomes (i.e., intended results). Each component is represented by a collection of criteria which represent the inputs, outputs, and outcomes of each participating party in the R&D collaboration. Each criterion is evaluated by corresponding metrics (i.e., indicators). The metrics are the evidence or information used to measure and evaluate the criteria. These metrics can be qualitative or quantitative based on the nature of the criteria evaluated. Each metric is measured by a corresponding scale, in which the type of assigned scale depends on the type of the metric whether it is quantitative or qualitative. For example, in this study, numerical scales are used to measure quantitative metrics. On the other hand, Likert scales, such as level of agreement or disagreement, are used to measure the attitudes and opinions towards qualitative metrics. However, it was found that some criteria can be evaluated using quantitative and qualitative metrics which are measured using both numerical scales and Likert scales respectively.

In this chapter, a generic logic model for evaluating R&D partnerships (in general) and a generic submodel for evaluating different IRCs within NSERC IRC program are proposed. The generic logic model is built to be applied to any R&D partnerships within or outside Canada. On the other hand, the generic submodel is built specifically to be applied to different IRCs within the NSERC IRC program.

In the next chapter, the generic submodel is verified through experts to integrate their vision and feedback regarding the listed criteria in the logic model. Evaluation of the NSERC IRC in SCMD is carried out by applying the proposed generic submodel as a pilot study. Also, statistical analysis is done on the collected data from university evaluation questionnaire to statistically correlate the inputs with outputs, and outputs with outcomes. Finally, a logic model for the university's role within the NSERC IRC in SCMD, which is validated using the pilot study, is presented to evaluate R&D partnership from the university perspective.

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CHAPTER 4 IMPLEMENTATION OF PROPOSED EVALUATION FRAMEWORK FOR CONSTRUCTION R&D PARTNERSHIPS: PILOT STUDY[4]

4.1 Introduction

In this chapter, the proposed submodel for R&D partnerships was further applied using a pilot study approach to evaluate a collaborative construction research program under the Natural Sciences and Engineering Research Council of Canada (NSERC) Industrial Research Program (IRC). The pilot study focused on one of such collaborative construction research programs, namely, the NSERC IRC in Strategic Construction Modeling and Delivery (SCMD). The participation of each party in this R&D partnership is represented by the parties which are reached and impacted by the R&D activities of the partnership as follows: the university consists of the chairholder of the NSERC IRC in SCMD and the associated research team members (i.e., postdoctoral fellows and graduate students); the construction industry consists of the industrial partners of the NSERC IRC in SCMD and the construction industry at large; and the government consists of NSERC, the federal funding agency. This chapter presents a statistical approach, based on university perspective, which helps in determining the relationship between the R&D partnership components so that the inputs and outputs can be better developed to achieve desired outcomes of each of the collaborating parties. Also, it presents a logic model for the university's role in the NSERC IRC in SCMD, which is internally validated using a pilot study, to evaluate the R&D partnership from the university perspective.

4.2 Questionnaire Development and Data Collection

Questionnaires were structured to evaluate the criteria for the different components of the R&D partnership corresponding to the roles of each collaborating party. Different studies were reviewed to investigate how the questionnaires can be structured to evaluate the different criteria

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(Awad 2012; Omar 2015). Three questionnaires were prepared for university research team, construction industry groups, and NSERC (i.e., government funding agency) as shown in Appendix B. Each questionnaire has three sections, which focus on the evaluation of the inputs, outputs, outcomes criteria. The different criteria were assessed based on the evaluation of the respective metrics, which are framed into structured questions. Each metric is evaluated by either a single or a series of defined questions, in which the designed questions are close-ended questions to enable the collection of specific data for evaluating the different criteria. The questionnaires were designed using a prospective cohort approach, such that the criteria are evaluated over a defined five-year time frame to monitor changes in the expected outcomes of each collaborating party. This time frame was chosen due to the fact that the duration of each NSERC IRC term is five years, with the possibility of renewal. The precise evaluation period for the questionnaires in Appendix B is intentionally unspecified to allow for future evaluation of the NSERC IRC over different evaluation periods. These evaluation questionnaires can be used in accordance with NSERC's specified reporting periods, which occur at 18, 36, 48, and 60 months.

The university evaluation questionnaire was piloted with the post-doctoral fellow and PhD students in order to ensure the clarity of questions and to maintain an adequate time frame for responding to the questionnaire. The participants in this pilot test found that most of the questions are clearly understandable; however, they had some minor comments on some of the questions' words which were taken in consideration and addressed. The participants in this pilot test were able to complete their responses within the assigned time frame of 30 minutes. Examples of designed questions measuring the university, construction industry, and NSERC inputs criteria are shown in Table 4.1, Table 4.2, and Table 4.3 respectively. The study presented in this thesis requires the participation of different parties involved in the R&D collaboration within the NSERC IRC in SCMD, and requires the collection of data from human subjects. Accordingly, the study was submitted to and approved by the University of Alberta Research Ethics Board to get research ethics approval before collecting data from the different participants.

Table 4.1. Examples of designed questions included in the university evaluation questionnaire

Input criterion	Sample of evaluation questions
Laboratories and facilities involved in R&D projects	• How many laboratories and/or research spaces (i.e., offices) are used to carry out activities for R&D projects within the IRC in SCMD (including all members of the research team)? __________laboratories ________ research spaces (offices) or □ N/A □ Do not know • How do you evaluate the quality of laboratories and/or research spaces (i.e., offices) used for R&D projects within the IRC in SCMD? 1- Poor 2- Fair 3- Good 4- Very good 5- Excellent or □ N/A □ Do not know
Time spent on R&D projects	• Monthly, over the past _________, how much time in hours do you spend working on R&D projects within the IRC in SCMD? ___________________ hours/month or □ N/A □ Do not know

Table 4.2. Examples of designed questions included in the construction industry evaluation questionnaire

Input criterion	Sample of evaluation questions
Organizational funding for R&D projects	• Annually, over the past _________, how much money does your organization invest in R&D projects within the IRC in SCMD? ____________________ CAD/year or □ N/A □ Do not know
University connections facilitated by R&D projects	• Over the past _________, how many R&D academic partners (i.e., university research teams) does your organization have within the IRC program in total, including the university research team for the IRC in SCMD?

Input criterion	Sample of evaluation questions
	___________________ academic partners or □ N/A □ Do not know • Over the past _________, how many R&D academic partners (i.e., university research teams) does your organization have outside of the IRC program in total? ___________________ academic partners or □ N/A □ Do not know

Table 4.3. Examples of designed questions included in the NSERC evaluation questionnaire

Input criterion	Sample of evaluation questions
Funding of different chairs in the IRC program	• Annually, over the past _________, how much money does NSERC invest in R&D projects within the IRC program (in general)? _____________________ CAD/year or □ N/A □ Do not know
Existing management tools and systems	• How do you evaluate the quality of the existing management tools and systems used by NSERC for the purpose of managing, supervising, and evaluating the IRC in SCMD? 1- Poor 2- Fair 3- Good 4- Very good 5- Excellent or □ N/A □ Do not know

4.3 Verification of the Submodel and Evaluation Questionnaires

The submodel and evaluation questionnaires were verified by consulting two experts via email as follows: (1) an individual experienced in evaluating research programs in Alberta Health; and (2) a construction industry professional who is working closely with the NSERC IRC in SCMD. The developed submodel was sent to both experts in an Excel sheet format, showing all criteria, metrics, and scales used to evaluate the R&D partnership components for each of the three collaborating parties. In addition, the university questionnaire was sent to the program evaluation expert, and the industry questionnaire was sent to the construction industry professional. The two experts reviewed the proposed submodel and questionnaires and sent their feedback to the researchers involved in this study.

The feedback from the program evaluation expert was helpful for the betterment of the overall logic model and the university questionnaire. Based on recommendations from the program evaluation expert, additional criteria and metrics were added to the proposed submodel, using a study done by Research Councils UK (RCUK) et al. (2014), which involved the collection of data to evaluate the components of a health research program. In addition, the program evaluation expert helped the researcher to modify the questionnaires in order to assess the pilot study collaboration over a defined period of time. Moreover, the program evaluation expert advised the researcher to better classify the outcomes based on the main impact categories that have been used by Alberta Innovates – Health Solutions (AIHS) (2015). The feedback from the program evaluation expert has been implemented in the proposed submodel presented in chapter three and in the evaluation questionnaires presented in Appendix B. Also, the feedback from the industry professional helped in determining future directions for industry participation in this research. The industry professional advised the researchers to better tailor the industry questionnaire in the future so that there is a specific questionnaire for each type of organization involved in the IRC. It was found that some questions were not applicable to the industry professional's organization, and this might be the case for other industry respondents. Accordingly, the researchers involved in this study have decided that the industry questionnaire should be modified in the future so that it can better capture the diversity in the types of organizations involved in the IRC, such as owners, owner associations, contractors, labour groups, companies, and associations.

4.4 Analysis of the Evaluation Results of the NSERC IRC in SCMD Based on University Perspective

The developed university evaluation questionnaire was then piloted with all research team members of the NSERC IRC in SCMD. Therefore, the statistical analysis carried out in this study is focused on the evaluation results of the university evaluation questionnaire. The subsequent analysis and key findings will be used to further extend the evaluation frameworks for the industry and government components. The evaluation questionnaires were distributed to the university research team members together with a consent form, and questionnaires were collected upon completion. Using a total population sampling approach, the evaluation questionnaire was distributed to all the 11 members of the research team, resulting in a 100% response rate. The respondents included the chairholder, one postdoctoral fellow, one technical writer, five doctoral students, and three master's students.

After the questionnaires were collected, an investigation of missing and completed responses was carried out as shown in Table 4.4. The respondent's level of experience in the research team played an important role in determining his/her response rate. Experience refers both to the length of time in which a respondent has been a member of the research team as well as the seniority of his/her position. For example, based on their experience, the chairholder and the postdoctoral fellow had the highest response rate among the research team members based on their experience; on average, they answered 98% of the questionnaire. On the other hand, senior doctoral students that have been members of the team for more than one year answered, on average, 73% of the questionnaire. The responses from one respondent (i.e., a junior master's student) were eliminated from the study due to a high percentage of missing responses (i.e., 91% of missing responses), which may lead to distortion of the analysis results. The eliminated responses are of the 11th respondent shown in Table 4.4.

Table 4.4. Investigation of missing and completed responses by each respondent in the university research team

Respondent number	Experience within the team (in years)	Position within the team	Number of missing answers	Percentage of completed responses
1	3.42	Doctoral student	10	92.37
2	0.67	Master's student	54	58.78
3	3.33	Doctoral student	45	65.65
4	0.92	Technical writer	37	71.76
5	0.75	Doctoral student	90	31.30
6	2.75	Doctoral student	51	61.07

Respondent number	Experience within the team (in years)	Position within the team	Number of missing answers	Percentage of completed responses
7	1.67	Master's student	42	67.94
8	0.75	Doctoral student	91	30.53
9	5.42	Postdoctoral fellow	1	99.24
10	19.42	Chairholder	3	97.71
11	0.75	Master’s student	119	9.16

However, in order to be able to proceed with other steps in inferential statistical analysis, the missing data had to be handled first. There are three main approaches to deal with missing data: (1) listwise (casewise) deletion, (2) pairwise deletion, and (3) mean substitution. In the listwise case deletion approach, cases with missing data will only be dropped if a small number of the cases (i.e., respondents) have missing data (Marsh 1998; Schlomer et al. 2010). However, this approach was not applicable to the pilot study analysis, as all respondents had some missing data. On the other hand, the pairwise deletion approach excludes missing data from the analysis and instead, only uses the existing data, which can produce very small, unequal data sets for each question and can lead to inaccurate results during correlation analysis (Marsh 1998; Schlomer et al. 2010). This approach was also not deemed to be appropriate due to the small data set involved in this study. To handle the missing data without distorting the small data set, the “mean substitution” approach was adopted. This method is widely used by researchers in the social work (Saunders et al. 2006), as it is a relatively easy technique to apply and does not require complicated calculations (Mundfrom and Whitcomb 1998). Instead, the mean substitution approach uses the mean of the total sample for a specific question or variable to fill the missing values of the variable (Kent 2015).

A measure of consistency, called Cronbach’s alpha coefficient, is statistically derived to verify that the responses of the university research team members towards the evaluation of the different criteria are consistent. The value of Cronbach’s alpha coefficient ranges between 0 and 1, in which the closer the Cronbach’s alpha coefficient is to 1.0, the greater the internal consistency of the data collected from the university research team towards the evaluation of the different criteria (George and Mallery 2003). George and Mallery (2003) gave interpretations of the values of Cronbach's alpha coefficient to measure the consistency among the responses as shown in Table 4.5. The values of Cronbach's alpha coefficient are interpreted as follows: 0.00–0.49 means "Unacceptable consistency"; 0.50–0.59 means "Poor consistency"; 0.60–0.69 means "Questionable consistency"; 0.70–0.79 means "Acceptable consistency", 0.80–0.89 means "Good consistency", and 0.90–1.00 means "Excellent consistency". Accordingly, the Cronbach's alpha coefficient was calculated for the data collected from the university research team towards the evaluation of the different criteria, and it had a value of 0.77 which means the consistency among the responses is acceptable and no need to re-collect data or exclude any of the responses

Table 4.5. Cronbach's Alpha Coefficient Consistency (George and Mallery (2003))

Cronbach's Alpha Coefficient Value (α)	**Consistency Result**
$1.0 \geq \alpha \geq 0.9$	Excellent consistency
$0.9 > \alpha \geq 0.8$	Good consistency
$0.8 > \alpha \geq 0.7$	Acceptable consistency
$0.7 > \alpha \geq 0.6$	Questionable consistency
$0.6 > \alpha \geq 0.5$	Poor consistency
$\alpha < 0.5$	Unacceptable consistency

Inferential statistical analysis (i.e., correlation analysis) was used to determine the correlation between the criteria for inputs and outputs, as well as the correlation between the criteria for outputs and outcomes. In order to carry out the analysis at the criteria level, the questionnaire responses had to be aggregated at the metric level to get a single score representing each criterion from the perspective of the respondent (Mazziotta and Pareto 2013; Hudrliková 2013). Since different types of scales (i.e., numerical and Likert scales) were used to measure the metrics, each applicable response was "normalized" by assigning it a value ranging from 0 to 1 in order to enable aggregation (Mazziotta and Pareto 2013; Hudrliková 2013). In addition, the metric questions showing identical responses by all respondents were removed, as these cannot be normalized. The process resulted in the removal of the following three outcomes criteria, as the associated metrics had identical responses: the short-term outcome criterion "better development in the infrastructure"; the medium-term outcome criterion "spin outs", and the long-term outcome criterion "maintaining a leading position among top-ranked research universities all over the world". Next, the normalized responses for the different metrics were aggregated. In the aggregation process, all metrics are assumed to have equal weights and to be independent of each other; arithmetic mean was used in aggregation, as it is the most common and transparent method used in aggregating different variables (Salzman 2003). The result of aggregation is represented by "composite index", a score ranging from 0 to 1, which is then divided over a five-point rating scale in order to indicate the respondent's overall evaluation of each criterion as shown in Table 4.6: 0.00–0.20 means "Poor"; 0.21–0.40 means "Fair"; 0.41–60 means "Good"; 0.61–0.80 means "Very good", and 0.81–1.00 means "Excellent".

Table 4.6. Interpretation of the overall evaluation of the criterion based on the mean of composite indices given by the respondents

Mean value of composite index for the criterion	**Interpretation of the value towards the overall evaluation of the criterion**
0.00 – 0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Good
0.61 – 0.80	Very good
0.81 – 1.00	Excellent

For example, the university output criterion "developing tools and solutions to problems through R&D projects" was evaluated using three metrics as shown in Table 4.7, in which each metric is measured by one question. The first question asks about the frequency at which the tools and solutions developed by the university research team are successfully implemented by the industrial partners of the IRC; the second question asks about the number of new software applications developed by the university research team over the past five years; and the third question asks about the quality of the outcomes (e.g., new tools, new solutions, new practices) produced by the IRC. The responses for these three questions (respectively) by the ten respondents were as follows: [4, 2, 4], [4, 2, 4], [3, 1, 4], [3, 2, 4], [3, 2, 4], [3, 2, 4], [3, 2, 4], [3, 2, 4], [2, 2, 4], and [4, 1, 4]. Each response was normalized on a scale of 0 to 1 using minimum-maximum approach, with the exception of the responses to the third question, which were identical. Finally, the normalized responses were aggregated using the arithmetic mean approach to get a single score representing each respondent's evaluation of the criterion "developing tools and solutions to problems through R&D projects" ; the results were as follows: 1.00, 1.00, 0.25, 0.75, 0.75, 0.75, 0.75, 0.75, 0.50, and 0.50. The mean of these responses was then calculated to derive the university research team's overall evaluation of this criterion, resulting in a score of 0.7, which means "Very good" on the aforementioned five-point rating scale. Different inputs, outputs, and outcomes criteria and metrics for the university's role in the IRC are shown in Appendix C, along with the composite indices and their corresponding interpretations.

Table 4.7. Example of evaluating an output criterion for university's role in the R&D partnership

Component	Criterion	Metric	Scale	Mean (Standard Deviation) for the criterion
Output	Developing tools and solutions to problems through R&D projects	• Frequency of implementing tools and solutions developed through R&D projects by the industrial partners of the IRC	1-Never, 2-Rarely, 3-Sometimes, 4-Often, 5-Usually	0.70 (0.23)
		• Number of software applications developed through R&D projects within the IRC over the past 5 years	Numerical values	
		• Level of quality of R&D projects results within the IRC	1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Excellent	

In the next stage, the inferential statistical analysis was carried out in order to accomplish the following tasks: (1) to determine the interdependencies between the whole sets (i.e., inputs, outputs, and outcomes) that represent the partnership; and (2) to determine the relationships between the individual criteria that make up the sets. Accordingly, the canonical correlation analysis (CCA) and Spearman's correlation analysis (SCA) methods were chosen. The CCA is a multivariate statistical model that is used to determine whether two sets of variables are dependent on one another (Hair et al. 1998). The CCA is also able to identify the strength of the overall relationships that may exist between two sets; this value is represented by the canonical correlation coefficient (R_c). In contrast, SCA is used to determine the strength of the relationships between each pair of variables (i.e., criteria), either within a set or between sets (Mukaka 2012); this value is represented by Spearman's correlation coefficient (r_s).

4.4.1 Canonical Correlation Analysis (CCA)

Canonical correlation analysis (CCA) was carried out to determine the interdependencies between the different sets included in the logic model (i.e., inputs and outputs, outputs and short-term outcomes, short-term outcomes and medium-term outcomes, and medium-term outcomes and long-term outcomes), and to investigate the strength of these relationships. However, CCA could not be applied to the complete sets due to a singularity error within the data set. A singularity error indicates that the correlation matrix between the loaded two sets is not positive definite (Rigdon 1997). A positive definite matrix has a determinant greater than 0.00001 (Field 2005). To overcome this obstacle, it is recommended that some of the sets' variables (i.e., criteria) be removed, specifically those that are not correlated at all (i.e., $r = 0$) or those that have a high correlation (i.e., $r > 0.9$) with the variables of the other set (Field 2005). In addition, it is critically important that variables within the same set with $r \geq 0.6$ be removed before applying CCA (Bros 2006). Accordingly, the singularity error problem was solved and the correlation matrix became positive definite matrix.

All CCA tests were run using Statistical Package for Social Science (SPSS) software. The first test was applied to the inputs and outputs sets; the second test was applied to the outputs and short-term outcomes sets; the third test was applied to the short-term and medium-term outcomes sets; and the fourth test was applied to the medium-term and long-term outcomes sets. The CCA outputs of the four tests were tabulated as shown in Table 4.8, Table 4.9, Table 4.10, and Table 4.11. The CCA output for the first test is represented as three roots. The first root, which shows the strongest relationship between the two sets, was used for the analysis (Hair et al. 1998; Bros 2006). The first root takes into account the maximum amount of variance among the variables in the sets compared to the other roots; the second root takes into account the maximum amount of variance that is not accounted for by the first root, and so on (Hair et al. 1998). The significance of the relationship was reviewed using the null hypothesis (H_0) that the two sets are independent of one another, which will be rejected at a significance level (p value) of 10% (i.e., 90% confidence interval). The proposed alternative hypothesis (H_1) is that the two sets are dependent on one another. The R_c value can be interpreted as r_s value to determine the strength of the relationship between the whole sets (Bros 2006). Accordingly, the following values of R_c determine the strength of the relationship between the whole sets: 0.00 means no linear relationship; 0.01–0.30 means a weak relationship; 0.31–0.70 means a moderate relationship; 0.71–1.00 means a strong relationship; and 1.00 means a perfect linear relationship (Ratner 2009).

Table 4.8. Output of CCA for the analysis between inputs and outputs sets

Root	Canonical correlation coefficient	Significance
1	0.984	0.031
2	0.789	0.269
3	0.666	0.000

Table 4.9. Output of CCA for the analysis between outputs and short-term outcomes sets

Root	Canonical correlation coefficient	Significance
1	0.857	0.900
2	0.751	0.903
3	0.314	0.968
4	0.143	0.760

Table 4.10. Output of CCA for the analysis short-term outcomes and medium-term outcomes sets

Root	Canonical correlation coefficient	Significance
1	0.994	0.345
2	0.897	0.634
3	0.807	0.654
4	0.148	0.000

Table 4.11. Output of CCA for the analysis medium-term outcomes and long-term outcomes sets

Root	Canonical correlation coefficient	Significance
1	0.852	0.558
2	0.668	0.579

When investigating the relationship between the inputs and outputs sets, it was found that R_c = 0.984, which shows that there is a strong positive relationship between the two sets as a whole. The significance level is 0.031, which is smaller than the adopted p value in this study (i.e., 0.1); this means that the H_0 (i.e., the outputs set is independent of inputs set) can be rejected in favour of H_1 (i.e., the outputs set is dependent on inputs set). Similarly, for the relationship between the outputs and short-term outcomes sets, it was found that R_c = 0.857 at a significance level of 0.900. In addition, for the relationship between the short-term outcomes and medium-term outcomes sets, it was found that R_c = 0.994 at a significance level of 0.345. Finally, for the relationship between the medium-term outcomes and long-term outcomes sets, it was found that R_c = 0.852 at a significance level of 0.558. For each of these three relationships, there is no sufficient evidence to reject H_0 in favour of H_1.

In summary, it can be concluded that there are interdependencies between the input and output sets as a whole. Also, it can be concluded that there are no interdependencies between the other sets as a whole. However, relationships may exist between the individual criteria of the independent sets, which were investigated using Spearman's correlation analysis (SCA), as explained in the next section.

4.4.2 Spearman's Correlation Analysis (SCA)

Spearman's Correlation Analysis (SCA) was adopted in the pilot study to investigate the relationships between the individual criteria, both within the same set and within different sets. Spearman's correlation analysis is considered to be the non-parametric version of Pearson's correlation analysis (Rebekić et al. 2015). There are some assumptions that must be followed before using Pearson's correlation analysis: 1) the two variables have significant linear relationship; 2) the two variables are continuous random variables; and 3) the two variables are normally distributed (Göktaş and İşçi 2011). If one of these assumptions is violated, the Pearson's correlation analysis will lead to inaccurate results. In contrast, the SCA is not restricted by these assumptions and is more rigorous to outliers than Pearson's correlation analysis (Mukaka 2012). For these reasons, SCA was adopted for the purpose of this pilot study.

SCA was carried out to investigate the correlation between the following variables: inputs criteria with each other; inputs criteria with outputs criteria; outputs criteria with each other, outputs criteria with short-term outcomes criteria, short-term outcomes criteria with each other, short-term outcomes criteria with medium-term outcomes criteria, medium-term outcomes criteria with each other, medium-term outcomes criteria with long-term outcomes criteria, and long-term outcomes criteria with each other. The SCA results are tabulated in Appendix C. The r_S values were checked to identify relationships among the criteria in which the significance level (*p* value) was below 10%. It was found that there is sufficient evidence to reject the the null hypothesis H_0 (i.e., there is no correlation existing between the criteria) in favour of the alternative hypothesis H_1 (i.e., there is a correlation existing between some of the criteria). The following values of r_S determine the strength of the relationship between the criteria: 0.00 means no linear relationship; 0.01–0.30 means a weak relationship; 0.31–0.70 means a moderate relationship; 0.71–1.00 means a strong relationship; and 1.00 means a perfect linear relationship (Ratner 2009). The type of the relationship depends on whether r_S is positive or negative. A positive r_S value indicates a positive relationship, which means that whenever the value of a variable (i.e., criterion) increases, the value of the other variable increases. In contrast, a negative r_S value indicates a negative relationship, which means that whenever the value of a variable increases, the value of the other variable decreases.

The interrelationships (inter-correlations) within each set were first investigated to determine the significant relationships among the criteria of each set. The results indicated that all sets have interrelationships among their criteria, with the exception of the medium-term outcomes set, as shown in Tables C.1, C.3, C.5, and C.8 in Appendix C. For example, in Table C.1, the results show that there is a strong positive relationship between two inputs criteria: (1) "industry connections facilitated by R&D collaborations"; and (2) "funding". These results suggest that if connections with industry increase, funding will also increase. However, it was found that there are some negative relationships among the individual criteria for the outputs and short-term outcomes sets. For example, in Table C.3, it was found that there is a moderate negative relationship between the following two outputs criteria: (1) "developing tools and solutions to problems through R&D projects"; and (2) "participating in advisory committee meetings of the IRC". These negative relationships should be further examined using a larger sample size (e.g., using data collected from different IRCs).

Next, the criteria for each set (i.e., inputs, outputs, and outcomes) were refined, based on their significant correlations with the criteria in the subsequent layer as shown in Tables C.2, C.4, C.6, and C.7 in Appendix C. For example, as shown in Table C.2 in Appendix C, the inputs criteria that have statistically significant correlations with any one of the outputs criteria have been selected. Accordingly, of the initial eight inputs criteria, two inputs criteria were eliminated. A similar process was repeated for the outputs and short-term outcomes sets; all eight outputs criteria were included, since all of these criteria have statistically significant correlations with the short-term outcomes criteria as shown in Table C.4 in Appendix C. Following the same approach for the rest of sets, two short-term outcomes criteria were eliminated; six medium-term outcomes criteria were eliminated; and five long-term outcomes criteria were eliminated. The interrelationships and complete relationships between the refined criteria for the different sets are shown in Appendix C in Figure 4.1 and Figure 4.2, respectively.

Finally, as shown in Figure 4.3, the criteria that were not correlated with any layers were removed and the different sets were simplified to show only dominant relationships. For example, in Figure 4.2, it was found that the three inputs criteria "qualified research team involved in R&D projects", "laboratories and facilities involved in R&D projects", and "trust in industrial partners working on R&D projects" are significantly correlated with the output criterion "publishing papers, technical reports, newsletters, books, and manuals/guides". Based on the correlation coefficients listed in Table C.2 in Appendix C, the relationship between the first input criterion and the single output criterion is stronger than the relationships between the other two inputs criteria and the output criterion, which means that the first relationship is dominant over the other relationships. Accordingly, the relationship with this output criterion was simplified by considering only the dominant relationship and eliminating the other two relationships. In addition, it was found that some criteria were not correlated with the any of the refined criteria. For example, in Figure 4.2, the output criterion “doing research in collaborative R&D teams” and the short-term outcome criterion “improved industrial relevance of research” were removed for this reason.

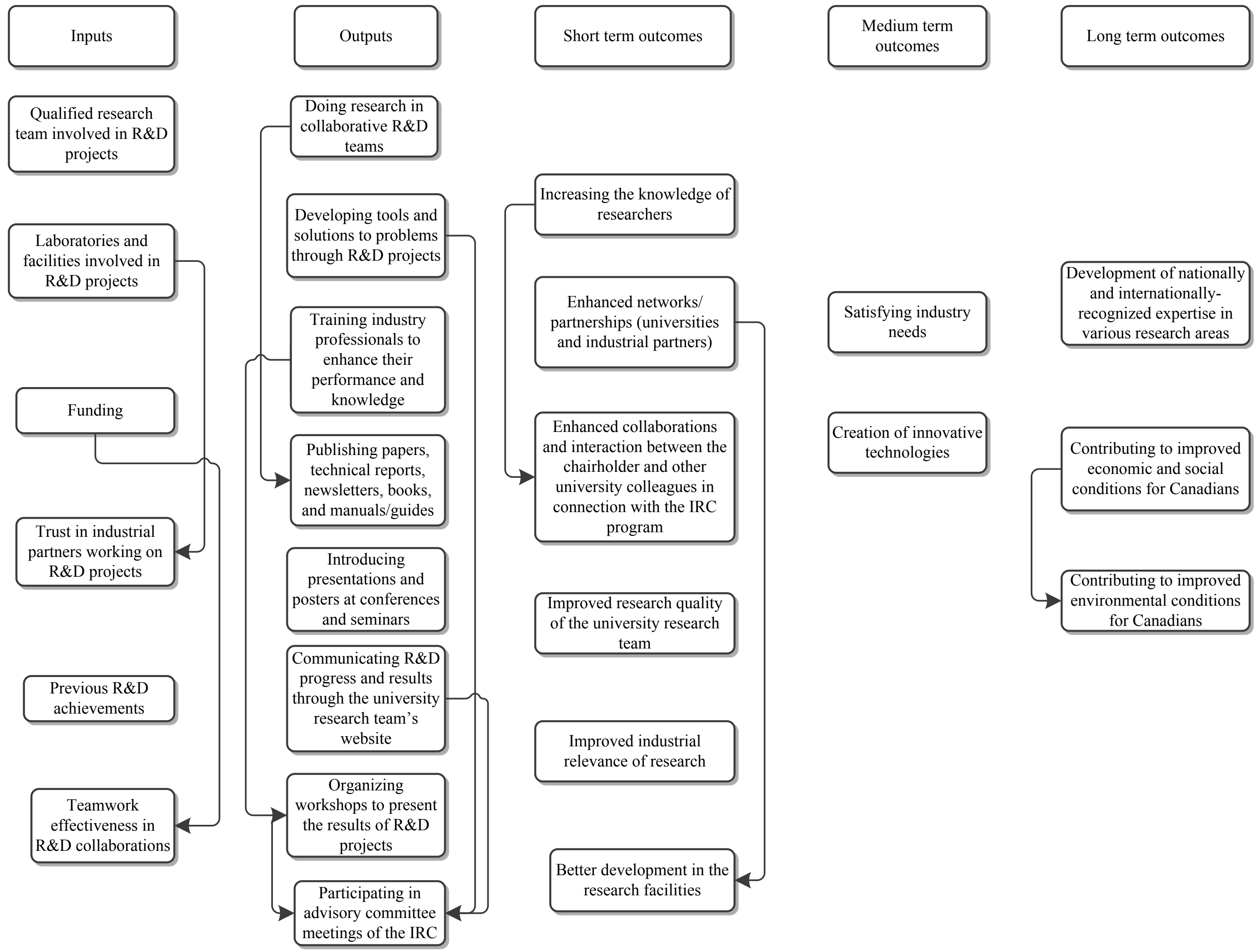

Figure 4.1. Interrelationships among the refined criteria of each set

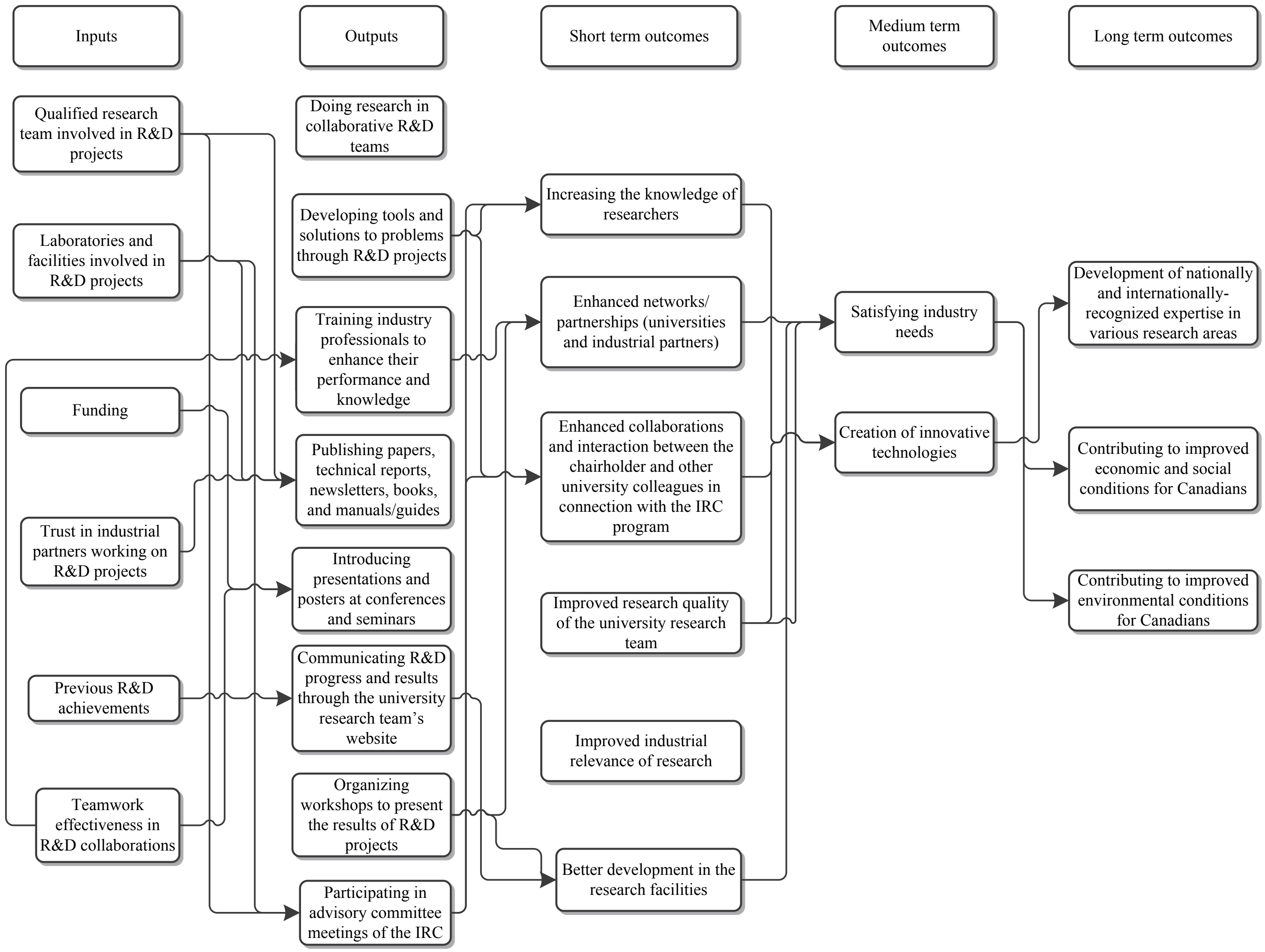

Figure 4.2. Complete relationships between the refined criteria of the sets

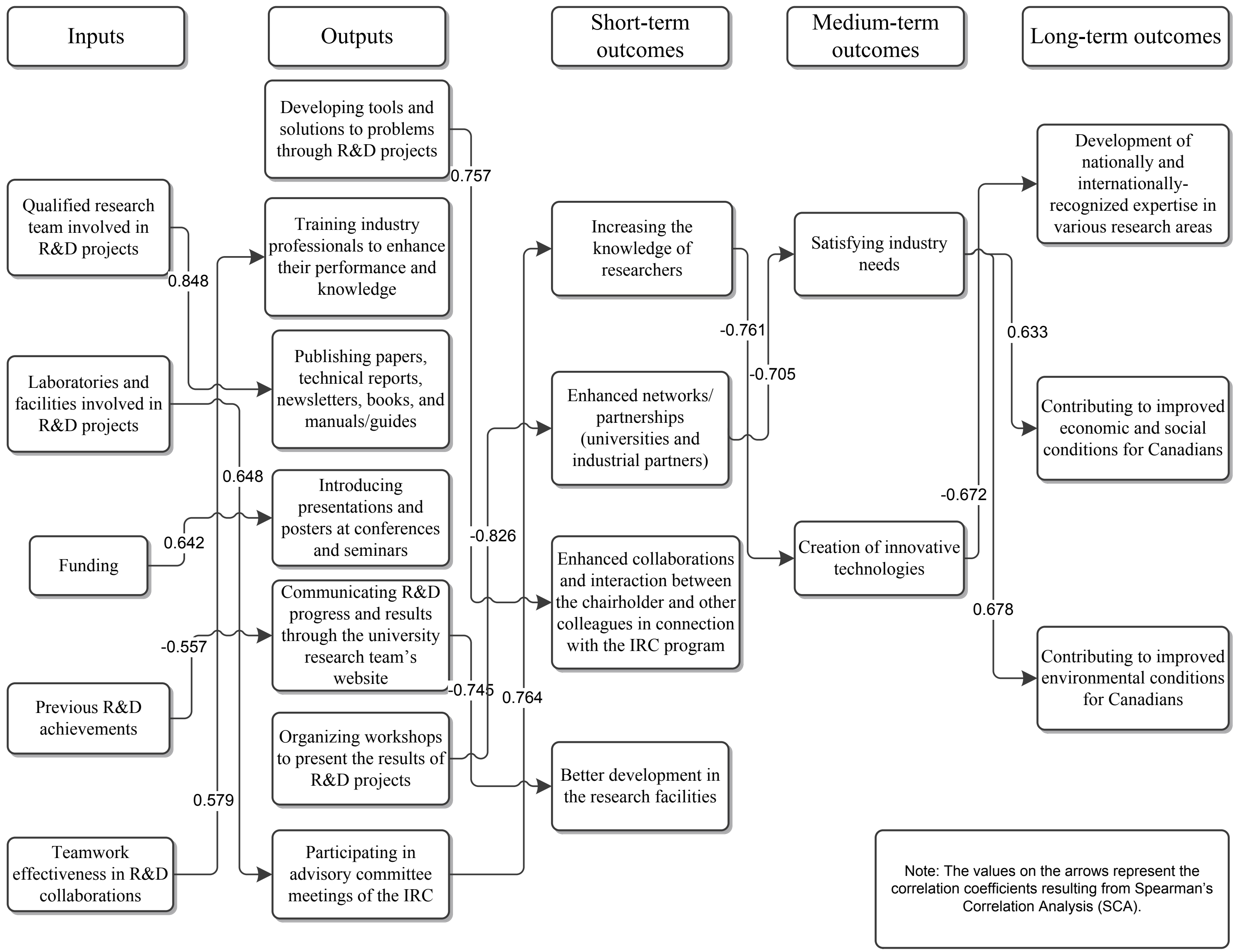

Figure 4.3. Simplified relationships among the components of the validated logic model

Figure 4.3 shows the final validated logic model representing the university's role within the NSERC IRC in SCMD. The refined criteria in the validated logic model can be used to evaluate the university's role within the NSERC IRC in SCMD. This final validated logic model illustrates the effect of each criterion in a set on the criteria of the subsequent layers. The validated model shows that a specific input criterion will lead to a specific output criterion, which will in turn result in specific outcomes criteria. Moreover, the model indicates the "chain of change" that connects the highly correlated criteria with each other, starting with inputs and ending with long-term outcomes. These chains of change can be used by the university research team to improve inputs and outputs criteria for better results in cases when outcomes are not meeting expectations.

For example, in the chains of change shown in Figure 4.3, it was found that the input criterion "laboratories and facilities involved in R&D projects" has a moderate positive relationship ($r_s = 0.648$) with the output criterion "participating in advisory committee meetings of the IRC". This output criterion has strong positive relationship ($r_s = 0.764$) with the short-term outcome criterion "increasing the knowledge of researchers". The composite indices of these input, output, and short-term outcome criteria (respectively) are as follows: 0.32, 0.67, and 0.40. These values suggest that the respondents' overall evaluations of the input criterion and the short-term outcome criterion are fair, while the overall evaluation of the output criterion is very good. Therefore, if the knowledge of researchers has not increased to the extent expected by the university research team, the inputs and outputs criteria included in this chain must be modified to reach the desired outcome. More specifically, an increase in the laboratories and facilities involved in R&D projects will lead to increased participation in advisory committee meetings for the IRC, and this will result in an increase in the knowledge of researchers.

The main purpose of the simplified model is to simplify the complexity of the relationships included in the complete model. However, the simplified model may not take into account the effect of some criteria on other subsequent layer's criteria. Accordingly, it is recommended to use the complete model if simplicity is not a main concern. Also, it is worth mentioning that the negatively correlated criteria shown in Figure 4.3 need to be further examined using a larger sample size (e.g., collecting data from different IRCs) to further evaluate the reasons for these negative correlations. The NSERC IRC program includes 300 IRCs, in which a sample size of 56 IRCs can be chosen randomly for collecting data based on a confidence interval of 90%. Using these 56 IRCs in future research may help to determine the reasons of the negative correlations which appeared in the university's logic model.

4.5 Concluding Remarks

This chapter presented a pilot study of applying the proposed evaluation framework to evaluate one of the IRCs within the NSERC IRC program, which is the NSERC IRC in SCMD. It presented the development and administration of the evaluation questionnaires with the university research team for the IRC in SCMD. Also, it presented a statistical approach to determine the relationship between the partnership components for the university participant of the R&D collaboration. The analysis carried out in this chapter is used to illustrate the research methodology proposed for evaluating R&D collaborations within any R&D partnership program, which can be applied to a larger sample size. The CCA showed that the university outputs set is dependent on the university inputs set. However, there is no other dependency between the outputs, short-term outcomes, medium-term outcomes, and long-term outcomes sets. The SCA showed the relationships between the individual criteria in a set with each other and also with the criteria included in another set. It was found that all the sets have interrelationships among their criteria except medium-term outcomes set. The relationships between the different sets' criteria were investigated based on dominant relationships and removal of criteria which are not correlated to any subsequent layers. This resulted in an internally validated refined logic model which can be used in the evaluation of the university's role within the NSERC IRC in SCMD so that better outcomes can be reached in the future. This internally validated logic model can be used in planning the university research team's inputs and activities in the R&D partnership, executing the planned research activities, tracking the intended outcomes of the R&D partnership, and controlling the inputs and outputs by taking corrective actions towards their improvement in order to achieve better outcomes in the future.

The proposed submodel presented in this study, previously investigated in chapter three, can be used to compare and assess the performance of different IRCs in the NSERC IRC program.

The proposed submodel can be used by different IRCs after refining and tailoring the different criteria listed in the submodel to suit the context of their research program before applying it in program evaluation. The proposed submodel is suitable for evaluating R&D program-based rather than R&D project-based based collaborations. In the next chapter, the conclusion of the research work carried out in this study is summarized. The contributions and limitations of this research are discussed, and recommendations for future research are outlined.

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CHAPTER 5 CONCLUSIONS AND FUTURE RESEARCH[5]

This chapter presents a review of the work conducted in this study and summarizes its contributions and limitations, as well as recommendations for future research.

5.1 Research Summary

Construction R&D programs play an important role in the social and economic development of countries. Unfortunately, industrial support for Canadian R&D partnerships has been noticeably decreasing over the past few years. Collaborative R&D partnerships between universities, industry groups, and government agencies must be evaluated on a regular basis. It is important that the involved parties be able to understand how their invested resources (i.e., inputs) and activities (i.e., outputs) affect their targeted outcomes if they are to produce better end results. However, there is no formal framework for evaluating construction R&D partnerships.

Accordingly, this thesis aims to introduce a structured methodology to develop a framework for evaluating construction R&D partnerships. If the expected outcomes are not meeting the expectations of the involved parties, the program can be enhanced by improving the inputs and outputs. The research in this thesis was carried out mainly in four main stages: (1) conducting a literature review on R&D partnerships and logic models; (2) compiling different evaluation criteria and their corresponding metrics and scales for the different components (inputs, outputs, and outcomes) of R&D partnerships; (3) developing logic models to represent the qualitative relationships between the different components of R&D partnerships; and (4) developing a methodology to evaluate R&D partnerships and to establish correlations among the different components of the partnership.

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5.1.1 First Stage

In the first stage, a comprehensive literature review was conducted on R&D partnerships and logic models, including the different types and structures of logic models and the development process. The current status of R&D partnerships in Canada was investigated and results showed a recent decline in the level of support being allocated to R&D projects by the private sector. Given that R&D partnerships are critical for the technological advancement of the construction industry, demonstrating their value is essential for encouraging investments. According to the reviewed studies, it was found that the construction research domain lacks a formal evaluation framework for assessing R&D collaborations. Despite the many advantages offered by logic models and their widespread use as a tool for program evaluation in a range of different research domains, logic models have not yet been applied in the context of construction R&D partnerships thus forming the basis for the research carried out in this study.

5.1.2 Second Stage

In the next stage, researchers agreed on the type and structure of the logic model to be used in representing R&D partnerships. It was decided that an outcome-approach model would be used for the purpose of assessing the pilot study partnership. This model was chosen because it takes into consideration the relationships between the partnership components and focuses on defining and achieving the desired results (i.e., short-term outcomes, medium-term outcomes, and long-term outcomes) by making strategic adjustments to the invested resources (i.e., inputs) and activities carried out through the program (i.e., outputs) (W.K. Kellogg Foundation (WKKF) 2004). Moreover, the outcome-approach model is considered to be one of the best options for evaluating program efficiency. The structure of the proposed logic model is following the structure of the logic models investigated extensively by Taylor-Powell and Henert (2008) and McCawley (2001), in which the model has three main components as follows: inputs (resources), outputs (activities and participation), and outcomes (intended results). Each partnership component in the model is represented by a list of criteria, which are evaluated using metrics and measured with scales. In the third chapter, different evaluation criteria and their corresponding metrics and scales were compiled using a number of R&D studies available in the literature. In addition, other metrics and scales were developed by the researchers to better fit the study context and to cover gaps in existing research regarding the evaluation of construction R&D partnerships.

In addition, in the third chapter, two developed logic models are presented: (1) a generic logic model; and (2) a generic submodel. The generic logic model represents the qualitative relationships between the different components of R&D partnerships for the roles of universities, industry groups, and government agencies (in general). In contrast, the generic submodel represents the different Industrial Research Chairs (IRCs) within the Natural Sciences and Engineering Research Council of Canada (NSERC) IRC program. The generic logic model was developed by tabulating the criteria that represent the components of R&D partnerships that are relevant to the role of each of the three collaborating parties, in which each model component consists of a number of different criteria. The generic submodel was developed by refining and tailoring the criteria established in the generic logic model for each party to suit the context of their participation in the NSERC IRC program.

5.1.3 Third Stage

In order to present a structured methodology on how to evaluate R&D partnerships and establish correlations among their components, the proposed evaluation framework (i.e., verified generic submodel and evaluation plan) was applied to a pilot study focused on the NSERC IRC in Strategic Construction Modeling and Delivery (SCMD). The structured evaluation methodology was developed through the following five steps:

a) Three questionnaires were designed to evaluate the different criteria corresponding to the components of the pilot study R&D partnership, as defined for each of the three collaborating parties (i.e., university, industry, and government). The first questionnaire was designed for the university research team for the NSERC IRC in SCMD, the second questionnaire was designed for the industrial partners of the NSERC IRC in SCMD, and the third questionnaire was designed for the NSERC. Each questionnaire is intended to evaluate the NSERC IRC in SCMD collaboration according to the role of the responding party.

b) The components of the proposed submodel and the developed questionnaires were verified by consulting two experts: (1) an individual experienced in program evaluation, and (2) a construction industry professional. This process helped to refine and verify the criteria stated in the generic submodel before it was applied to the pilot study, and to make sure that the content of the questionnaires was relevant and unambiguous. Moreover, the feedback provided by the construction industry professional was helpful in determining future directions for industry participation in this research (previously discussed in chapter four).

c) The university evaluation questionnaire was administered with the university research team for the NSERC IRC in SCMD.

d) The data collected through the university questionnaire were analysed to evaluate the R&D partnership from university's perspective and establish correlations among the inputs, outputs, and outcomes related to the university's role within the NSERC IRC in SCMD. The analysis was carried out using canonical correlation analysis (CCA) and Spearman's correlation analysis (SCA). CCA is used to determine the strength of the relationship between whole sets: inputs and outputs, outputs and short-term outcomes, short-term outcomes and medium-term outcomes, and medium-term outcomes and long-term outcomes. In contrast, SCA is used to determine correlations among individual criteria, both within a set and among different sets.

e) The internally validated logic model for the university's role within the NSERC IRC in SCMD was presented based on the analysis results. This internally validated logic model can be used in the future to evaluate the university's role within the NSERC IRC in SCMD. This internally validated logic model can be used in planning the university research team's investments and activities in the partnership, executing different research activities, and tracking the expected outcomes of the R&D partnership, and controlling the inputs and outputs by taking corrective actions towards their improvement in order to achieve better outcomes in the future.

5.2 Research Contributions

This thesis has produced a wide range of contributions that will positively impact the three main collaborating parties in Canadian construction R&D partnerships (i.e., universities, industry groups, and government agencies). Some of these contributions are more relevant to researchers (e.g., university) and are thus classified as academic contributions, while other contributions are more relevant to the construction industry or the government and are classified as industrial or governmental contributions.

5.2.1 Academic Contributions

The academic contributions of this research are as follows:

- The different components of R&D partnerships relevant to the role of the university were defined.

- Different evaluation criteria were compiled and various metrics and scales were assigned to the criteria to assess the university's role in R&D partnerships.

- A generic logic model (used to visualize and evaluate the university's role in R&D partnerships in general), and a generic submodel (used to visualize and evaluate the university's role within different IRCs) were introduced.

- A structured methodology was presented for the development of an integrated logic model and evaluation plan that can be used in identifying and assessing qualitative relationships among the different components of R&D partnerships.

- This research demonstrated the importance of evaluating different IRCs within the NSERC IRC program in order to improve collaboration and communication among the invested parties. The proposed framework was used to assess the university's role within the NSERC IRC in SCMD, in which the inputs, outputs, and outcomes relevant to the university were evaluated on a scale ranging from "Poor" to "Excellent", as shown in Appendix C. These evaluation results highlight which inputs and outputs need to be improved in the future by the university research team for this IRC in order to bring the actual outcomes of the partnership closer in line with their desired expectations.

- Crucial areas of investment were identified for the university research team for the NSERC IRC in SCMD. The "chains of change", which are previously investigated in chapter four, shows the investments and activities for the university's role within the NSERC IRC in SCMD which lead to the desired outcomes. This information can help the university research team for the NSERC IRC in SCMD to focus on inputs and outputs that are not progressing to a satisfactory level in order to achieve better results and enhance future collaborations.

5.2.2 Industrial Contributions

The industrial contributions of this research are as follows:

- Clear definitions of the different components of R&D partnerships that are relevant to the role of industry groups were introduced.

- Different evaluation criteria, metrics, and scales were presented to assess the role of industry groups in R&D partnerships.

- A generic logic model (used for visualizing and evaluating the role of industry groups in R&D partnerships in general) and a generic submodel (used for visualizing and evaluating the role of industry groups within different IRCs) were introduced.

5.2.3 Governmental Contributions

The governmental contributions of this research are as follows:

- Clear definitions of the different components of the government's role in R&D partnerships were introduced.

- Different evaluation criteria, metrics, and scales were presented to assess the government's role in R&D partnerships.

- A generic logic model (used for visualizing and evaluating the government's role in R&D partnerships in general) and a generic submodel (used for visualizing and evaluating the role of NSERC's role within different IRCs) were introduced.

5.3 Research Limitations and Recommendations for Future Research and Development

The following limitations were encountered in the course of this study:

1) The construction industry and government evaluation questionnaires were not administered. Therefore, the roles of the government and the industrial partners of the IRC were not evaluated and the validated logic model components for these two parties were not presented.

2) The construction industry evaluation questionnaire was designed in a generic way to be answered by the industrial partners without regard for the nature of the work carried out by an organization. It is possible that some of the questions may not be applicable to certain respondents, depending on the sort of organization they represent. For example, there may be many different types of industrial partners involved in an IRC such as owners, owner associations, contractors, labour groups, companies, and associations.

3) No weights were assigned to the criteria listed in the different sets (i.e., inputs, outputs, and outcomes) of the logic model; instead, all the criteria were assumed to be equally weighted. However, participants may have different opinions regarding the importance of some criteria over others towards evaluating their inputs, outputs, and outcomes.

4) No weights were assigned to the metrics that were used to evaluate the different criteria; instead, all metrics were assumed to have equal weights. However, in optimal circumstances, participants may assign different weights to metrics that will vary according to the importance of some metric in evaluating a particular criterion.

5) Many of the long term outcomes criteria are subjective and measured using qualitative metrics, and this may lead to discrepancies among the different responses. Consequently, further survey techniques and methodologies, such as measurement theory, need to be investigated to better define the outcomes.

6) Given that data were not collected from different IRCs, only a small sample size used in the pilot study. Consequently, some negative correlations appeared between the individual criteria, which need to be further examined using larger sample size to evaluate the reasons for these negative correlations (previously discussed in chapter four).

Utilizing the evaluation framework developed in this study, the following topics could be explored in the future to expand the scope of research in this area:

1) Carrying out further research focused on evaluating the roles of industry groups and NSERC within the NSERC IRC program. The industry and government evaluation questionnaires need to be administered on an interview basis in order to ensure the clarity of the questions to the respondents, and to facilitate the data collection process from both parties.

2) Refining the industry questionnaire to better capture variation within the types of organizations that may be involved in NSERC IRCs that are conducting construction research. The industry questionnaire needs to be refined so that it can address the work nature of different industrial partners of the IRC such as owners, owner associations, contractors, labour groups, companies, and associations.

3) Collecting data from different NSERC IRCs to further investigate the reasons for the negative correlations that appeared among the different criteria (i.e., an increase in one

criterion lead to a decrease in another). For example, the input criterion "previous R&D achievements" was found to have a moderate negative relationship with an output criterion "communicating R&D progress and results through the university research team's website". The researchers acknowledge that this result may not be realistic, as an increase in previous R&D projects should increase communication about these projects through the university research team's website.

4) Using the framework developed in this study for continuous evaluation of the NSERC IRCs, so as to improve the program by focusing on the invested resources and activities affecting the outcomes which are not meeting the expectations. The developed evaluation questionnaires can be used in accordance with NSERC's specified reporting periods, which occur at 18, 36, 48, and 60 months. Based on the evaluation results, the progress of inputs, outputs, and outcomes can be examined to identify and adjust the inputs and outputs that are progressing unsatisfactorily and leading to lagging outcomes in order to achieve better results in the future.

5) Collecting experts' opinions on the weights of the different criteria listed in the logic model which represents their collaborating party's role in the R&D partnership. Also, data collection and analysis can be used to develop the weights of the different criteria. Consequently, some criteria would have higher weights than other criteria in evaluating the different components (i.e., inputs, outputs, and outcomes) of each collaborating party in the R&D partnership.

6) Development of an approach to allow respondents from each of the three collaborating parties to assign weights to the different metrics, based on the relative importance of a metric to a particular criterion. Consequently, some metrics would have greater influence over others on the evaluation of a specific criterion.

7) Investigation of other aggregation methods, such as principal component analysis (PCA) and multi-criteria analysis (MCA), which are used in aggregating the responses of each

respondent from the metrics level to the criteria level. These aggregation methods do not assume that all metrics are independent of one another and have equal weights.

8) Applying advanced mapping techniques, such as fuzzy expert systems (FES) and artificial neural networks (ANN), to the developed framework to provide a more comprehensive understanding of the relationships between the components of the logic model. For example, a FES could be developed to relate inputs to outputs and outputs to outcomes. Once the relationships are established, the logic model could then be used to predict the outputs and outcomes based on the inputs, which would provide the collaborating parties with an easy and direct approach to identify chains of change (previously investigated in chapter four).

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APPENDICES

APPENDIX A: CRITERIA AND CORRESPONDING METRICS FOR THE PROPOSED SUBMODEL FOR EVALUATING THE R&D COLLABORATION WITHIN THE NSERC IRC

A.1. Input criteria and corresponding metrics for the university's role in the proposed submodel

Input criterion	Metric	Type of metric
Qualified research team involved in R&D projects	• Total years of research and industrial work experience of the researchers involved in R&D projects • Personal management • Research and analysis • Project and task management • Commitment to quality • Professional behavior • Continuous learning	Quantitative Qualitative Qualitative Qualitative Qualitative Qualitative Qualitative
Laboratories and facilities involved in R&D projects	• Number of Laboratories and/or research spaces • Quality of Laboratories and/or research spaces	Quantitative Qualitative
Industry connections facilitated by R&D collaborations	• Number of R&D industrial partners of the IRC	Quantitative
Funding	• Amount of funds in Canadian dollars provided by the different partners of the IRC • Level of satisfaction of remuneration • Level of satisfaction of in-kind contributions provided by the partners of the IRC	Quantitative Qualitative Qualitative
Trust in industrial partners working on R&D projects	• Integrity • Competence • Dependability	Qualitative
Time spent on R&D partnership	• Number of hours spent monthly on R&D projects within the IRC	Quantitative
Previous R&D achievements	• Number of R&D projects with industry participants of the IRC completed on time and on budget • Total number of R&D projects with industry participants of the IRC	Quantitative Quantitative
Teamwork effectiveness in R&D collaborations	• Perceived cohesion • Perceived communication • Perceived support	Qualitative Qualitative Qualitative

A.2. Input criteria and corresponding metrics for the industry's role in the proposed submodel

Input criterion	Metric	Type of metric
Organizational funding for R&D projects	• Total amount of Canadian dollars invested in R&D projects within the IRC	Quantitative
In-kind contributions supplied by the organization to the university	• Expenditures on in-kind contributions (materials, equipment, time of technicians, etc.) supplied by the organization to university for R&D projects within the IRC	Quantitative
Qualified Industry professionals involved in R&D projects	• Number of participating industry professionals in R&D projects • Total years of research and industrial work experience of the industry professionals involved in R&D projects • Personal management • Research and analysis • Project and task management • Commitment to quality • Professional behaviour • Continuous learning	Quantitative Quantitative Qualitative Qualitative Qualitative Qualitative Qualitative Qualitative
Time spent per one research project in R&D partnership	• Number of hours spent monthly on R&D projects within the IRC	Quantitative
Previous successful collaborative R&D projects	• Number of R&D projects with university research team for the IRC which lead to high profits • Number of R&D projects with university research team for the IRC done on time and on budget • Total number of R&D projects with university research team for the IRC	Quantitative Qualitative Qualitative
Trust in academic partners working on R&D projects	• Integrity • Competence • Dependability	Qualitative Qualitative Qualitative
Teamwork effectiveness in R&D collaborations	• Perceived cohesion • Perceived communication • Perceived support	Qualitative Qualitative Qualitative
Access to technical data	• Level of agreement on providing the university research team for the IRC with access to different technical data	Qualitative
University connections facilitated by R&D collaborations	• Number of R&D academic partners (universities' research teams) within the NSERC IRC program in total	Quantitative

A.3. Input criteria and corresponding metrics for the NSERC's role in the proposed submodel

Input criterion	Metric	Type of metric
Qualified personnel involved in R&D partnerships	• Total years of experience of the personnel working at NSERC and with the IRC specifically	Quantitative
	• Personal management	Qualitative
	• Project and task management	Qualitative
	• Commitment to quality	Qualitative
	• Professional behaviour	Qualitative
	• Continuous learning	Qualitative
Funding of different chairs in the IRC program	• Total amount of Canadian dollars invested in R&D projects within the IRC	Quantitative
Time spent on R&D projects	• Number of hours spent monthly on R&D projects within the IRC	Quantitative
Previous R&D achievements	• Number of R&D projects within IRC program in total completed on time and on budget	Quantitative
	• Total number of awarded IRCs since the beginning of the NSERC IRC program	Quantitative
Existing management tools and systems	• Level of quality of existing management tools and systems	Qualitative
Existing partnerships	• Total number of academic and industrial partners within the NSERC IRC program	Quantitative
Knowledge of market and government needs	• Level of awareness of the IRC towards market and government needs	Qualitative

A.4. Output criteria and corresponding metrics for the university's role in the proposed submodel

Output criterion	Metric	Type of metric
Doing research in collaborative R&D teams	• Frequency of carrying out R&D projects in collaboration with industrial partners of the IRC	Qualitative
	• Number of basic, applied, and basic and applied R&D projects carried out within the IRC	Quantitative
	• Level of satisfaction with the collaboration on R&D projects within the IRC	Qualitative
	• Time spent in years by graduate students (i.e., doctorate and master's students) to complete their degrees within the IRC	Quantitative
	• Number of graduate students posted at industrial partners' organization and/or job sites within the IRC	Quantitative
Developing tools and solutions to problems through R&D collaborations	• Frequency of implementing tools and solutions developed through R&D projects by the industrial partners of the IRC	Qualitative
	• Number of software applications developed through R&D projects within the IRC	Quantitative
	• Level of quality of R&D projects results within the IRC	Qualitative
Training of industry professionals to enhance their performance and knowledge	• Frequency of providing training to industry professionals	Qualitative
	• Number of training workshops carried out by university for industry	Quantitative
	• Number of trained industry professionals	Quantitative
	• Level of satisfaction of the outcomes of the training provided	Qualitative
Publishing papers, technical reports, newsletters, books, and manuals/guides	• Number of different publications introduced by the university research team for the IRC	Quantitative
	• Level of quality of the different publications	Qualitative
Introducing presentations and posters at conferences and seminars	• Number of posters and research posters introduced at conferences and seminars	Quantitative
	• Level of quality of the presentations and research posters introduced by the university research team for the IRC	Qualitative
Communicating R&D progress and results through the university research team's website	• Frequency of updating information on the IRC website regarding the progress of R&D projects	Qualitative
	• Level of quality of the website content regarding the R&D projects	Qualitative
Organizing workshops to present the results of R&D projects	• Number of organized workshops by the university research team for the IRC to present outcomes and results of R&D projects	Quantitative
	• Level of quality of the organized workshops by the university research team for the IRC	Qualitative

Output criterion	Metric	Type of metric
Participating in advisory committee meetings of the IRC	• Number of management and technical advisory committee meetings in which the IRC chairholder participate in	Quantitative

A.5. Output criteria and corresponding metrics for the industry's role in the proposed submodel

Output criterion	Metric	Type of metric
Working with university in execution of research projects	• Frequency of working with university in the execution of R&D projects within the IRC	Qualitative
	• Number of basic, applied, and basic and applied R&D projects carried out within the IRC	Quantitative
	• Level of satisfaction with the collaboration with university on R&D projects within the IRC	Qualitative
	• Number of graduate students posted at the organization and/or job sites within the IRC	Quantitative
Assisting the university in the development of tools to address market needs	• Frequency of assisting university in the development of tools to address the needs of the market within the IRC	Qualitative
	• Number of software applications the organization assisted in their development	Quantitative
	• Level of quality of the outcomes of R&D projects within the IRC	Qualitative
Providing industry training to graduate students by offering internships at the organization	• Frequency of training graduate students by providing them with internships at the organization	Qualitative
	• Number of internships provided to graduate students	Quantitative
	• Number of graduate students trained through internships	Quantitative
	• Level of satisfaction of the outcomes of the training provided	Qualitative
Providing technical support to the university research team on R&D projects	• Frequency of providing technical support to the university research team for the IRC	Qualitative
	• Level of quality of the technical data provided by the organization to the university research team for the purpose of R&D projects within the IRC	Qualitative
	• Level of quality of the technical support provided by the organization for solving technical problems within the IRC	Qualitative
Using university facilities and laboratories for the purpose of R&D projects	• Frequency of using university facilities and laboratories to carry out activities for R&D projects within the IRC	Qualitative
	• Level of quality of the university facilities and laboratories used by the organization to carry out activities for R&D projects within the IRC	Qualitative
Participating in advisory committee meetings of the IRC	• Number of management and technical advisory committee meetings in which the organization participate in as industrial partner of the IRC	Quantitative

A.6. Output criteria and corresponding metrics for the NSERC's role in the proposed submodel

Output criterion	Metric	Type of metric
Linking industry with university through R&D collaborations	• Frequency of linking industrial partners with the university research team through the IRC to collaborate on R&D projects	Qualitative
	• Number of basic, applied, and basic and applied R&D projects carried out within the IRC	Quantitative
	• Level of satisfaction with the collaborative work done by NSERC with the academic and industrial partners of the IRC	Qualitative
Attracting highly qualified personnel (HQP) (i.e., Masters Students, and Doctoral Students) to work on different R&D projects	• Frequency of attracting HQP to work on R&D projects via the IRC by supporting them financially	Qualitative
	• Number of scholarships offered by NSERC offer for doctoral and master's students within the IRC	Qualitative
	• Value of scholarships offered by NSERC offer for doctoral and master's students within the IRC	Quantitative
	• Level of quality of the personnel hired (i.e., graduate students and postdoctoral fellows) by the IRC chairholder to work on different R&D projects	Qualitative
Publishing of communication materials (i.e., guides, reports, announcements, etc.)	• Frequency of publishing communication materials by NSERC for the IRC program	Qualitative
	• Level of quality of the different publications	Qualitative
Updating information on NSERC website	• Frequency of updating information on NSERC's website regarding awards, grants, scholarships, and university-industry collaborations related to the IRC program	Qualitative
	• Level of quality of the website content regarding awards, grants, scholarships, and university-industry collaborations related to the IRC program	Qualitative
Review and selection of applications for IRC funding	• Number of received applications by NSERC for IRC funding	Quantitative
	• Acceptance rate of proposals submitted for IRC funding	Quantitative
Administration and management of grants and the renewal process	• Number of funded IRC chairholders by NSERC	Quantitative
	• Level of funding provided by NSERC to the IRC	Qualitative
Evaluation of progress reports from chairholders	• Frequency of evaluating the progress reports submitted by the IRC	Qualitative
	• Level of agreement on the clear presentation of the objectives of the IRC in the progress reports	Qualitative
	• Level of agreement on the progress made by the IRC towards achieving the defined objectives	Qualitative
	• Frequency of deviations done by the IRC from the originally defined objectives in the progress reports	Qualitative

Output criterion	**Metric**	**Type of metric**
	• Level of impact of the deviations from originally defined objectives on the progress of the IRC	Qualitative
	• Types of problems faced in evaluating the IRC	Qualitative
	• Frequency of facing problems during evaluation	Qualitative
Providing feedback on progress reports from chairholders	• Frequency of providing feedback on the progress reports submitted by the IRC	Qualitative
	• Level of quality of the progress reports submitted by the IRC	Qualitative
Providing training workshops for university and industry groups	• Number of training workshops organized by NSERC for industrial and academic partners of the IRC	Quantitative
	• Number of trained industry professionals and university researchers within the IRC	Quantitative
	• Level of satisfaction with the outcomes of the training workshops provided by NSERC to university researchers and industry professionals within the IRC	Qualitative

A.7. Outcome criteria and corresponding metrics for the university's role in the proposed submodel

Class of outcomes	Outcome criterion	Metric	Type of metric
Short-term Outcomes	Graduating highly experienced students	• Level of increase in the experience of the university research team by participating in R&D projects within the IRC	Qualitative
	Better understanding of industry needs	• Level of improvement in the awareness of industry needs after participating in R&D projects within the IRC	Qualitative
	Linking scientific theories with practical applications	• Level of alignment of R&D projects within the IRC with practical industry needs	Qualitative
	Increased university research capacity in an area directly related or complementary to the IRC	• Level of increase in the university's research capacity since the start of the IRC	Qualitative
	Increasing the knowledge of researchers	• Level of increase in the knowledge and skills of the university research team by participating in R&D projects within the IRC	Qualitative
	Fostering improved collaboration and stable relationships with industry	• Level of improvement in collaboration between university and industry by working together on R&D projects within the IRC	Qualitative
	Enhanced networks/partnerships (universities and industrial partners)	• Level of enhancement in the collaboration and interaction between the IRC chairholder and other industrial partners outside the IRC • Number of existing industrial partners who extend and discontinue their participation in the IRC at each renewal • Number of new industrial partners who join the IRC at each renewal • Number of industrial partners outside the IRC in which the university research team collaborate with based on successful R&D projects within the IRC	Qualitative Quantitative Quantitative Quantitative
	Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	• Level of enhancement in collaboration and interaction between the IRC chairholder other colleagues in connection with the IRC program	Qualitative
	Improving the reputation of researchers among their peers	• Level of enhancement in the reputation of the university research team by participating in R&D projects within the IRC • Number of awards won regionally, nationally, and internationally by the university research team members by participating in R&D projects within the IRC	Qualitative Quantitative
	Improved research quality of the university research team	• Level of improvement in the research conducted by the university research team since the start of the IRC	Qualitative
	Improved industrial relevance of research	• Level of improvement in the industrial relevance of research conducted by the university research team since the start of the IRC	Qualitative

Class of outcomes	Outcome criterion	Metric	Type of metric
Medium-term Outcomes	Better development in the research facilities	• The increase in the amount of funds in Canadian dollars invested in research facilities since the start of the IRC	Quantitative
	Better development in the infrastructure	• The increase in the amount of funds in Canadian dollars invested in infrastructure since the start of the IRC	Quantitative
	Satisfying industry's needs	• Level of satisfaction of industry needs by the results of R&D projects carried out through the IRC	Qualitative
	Creation of innovative technologies	• Number of patentable, licensable, and innovative products developed through R&D projects within the IRC • Number of transferred products to industrial partners within the IRC • Number of innovative processes developed through R&D projects within the IRC	Quantitative Quantitative Quantitative
	Spin outs	• Name of the company • Registration number of the company • The date on which the company was established • The number of salaried people employees in this company • Description for the company • Description of any notable impacts from the company • URL of the company	Qualitative Quantitative Qualitative Quantitative Qualitative Qualitative Qualitative
	Enhanced academic reputation of the department and/or university	• Level of enhancement in the reputation of the department and/or university by participating in R&D projects with the industrial partners of the IRC • Number of new graduate student enrolled in the university research team for the IRC	Qualitative Quantitative
	Enhanced feedback mechanism for better communication and collaboration with industry	• Level of enhancement in the feedback mechanism with industry after working together on different R&D projects within the IRC	Qualitative
	Expansion of the research program	• Level of increase in the research themes explored by the university research team by working with industrial partners of the IRC	Qualitative
	Enhancement of the management system for R&D projects	• Level of enhancement of R&D projects' management system by working with industrial partners of the IRC on R&D projects	Qualitative
	Employment of highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers)	• Number of trained university research team members within the IRC • Number of hired HQP from the university research team by the industrial partners of the IRC • Number of hired HQP from the university research team by other universities	Quantitative Quantitative Quantitative

Class of outcomes	Outcome criterion	Metric	Type of metric
Long-term Outcomes	Maintaining a research leading position among top-ranked universities all over the world	• Rank of Faculty of Engineering at the university according to QS World University Ranking System	Quantitative
	Development of nationally and internationally-recognized expertise in various research areas	• Level of influence of the different research themes in the construction domain nationally and internationally	Qualitative
	Enhancing Canada's level of technological innovation on a global scale	• Level of effect of the different research themes explored by the IRC on enhancing Canada's level of technological innovation	Qualitative
	Enhancing the global competitiveness of the Canadian economy	• Level of effect of the different research themes explored by the IRC on enhancing the global competitiveness of the Canadian economy	Qualitative
	Contributing to improved economic and social conditions for Canadians	• Level of effect of the different research themes explored by the IRC on improving the economic and social conditions for Canadians	Qualitative
	Contributing to improved environmental conditions for Canadians	• Level of effect of the different research themes explored by the IRC on improving the environmental conditions for Canadians	Qualitative

A.8. Outcome criteria and corresponding metrics for the industry's role in the proposed submodel

Class of outcomes	Outcome criterion	Metric	Type of metric
Short-term Outcomes	Fostering improved collaboration with the university on R&D projects	• Level of improvement of R&D collaborations with university research team for the IRC	Qualitative
	Increasing the experience of employees	• Level of experience increase of employees after participating in R&D projects within the IRC	Qualitative
	Increasing the knowledge of employees	• Level of knowledge increase of the employees by participating in R&D projects within the IRC	Qualitative
	Improving the organization's national competitive position among other organizations	• The annual percentage improvement of the company's share in the domestic market after being involved in R&D projects within the IRC	Quantitative
	Improved research quality of the university research team	• Level of improvement in the research conducted by the university research team since the start of the IRC	Qualitative
	Improved industrial relevance of research	• Level of improvement in the industrial relevance of research conducted by the university research team since the start of the IRC	Qualitative
	Better understanding of market needs	• Level of improvement in the awareness of market needs after participating in R&D projects within IRC	Qualitative
Medium-term Outcomes	Hiring highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) to work at the organization	• Number of HQP from the IRC hired by the organization	Quantitative
	Enhanced feedback mechanisms for better communication and collaboration with the university on R&D projects	• Level of enhancement in the quality of feedback after working with the university research team for the IRC on different R&D projects	Qualitative
	Changes in the organization's practices and strategies leading to improved industry performance	• Level of improvement the organization's practices and strategies as a result of involvement in R&D projects within the IRC • Level of improvement in the organization's awareness towards international construction standards as a result of involvement in R&D projects within the IRC	Qualitative Qualitative
	Sharing in the ownership of innovative results and products developed through R&D partnerships	• Number of patentable, licensable, and innovative products developed through R&D projects within the IRC • Number of transferred products to the organization through the R&D projects within the IRC • Number of innovative processes developed through R&D projects within the IRC	Quantitative Quantitative Quantitative

Class of outcomes	Outcome criterion	Metric	Type of metric
Long-term Outcomes	Enhancement of the management system for construction projects	• Level of enhancement in the quality of the organization's management system for construction projects by working with the university research team for the IRC on R&D projects	Quantitative
	Higher profits for the organization and better project and organizational performance	• Annual reduction in the number of accidents at the organization after participating in R&D projects within the IRC • The percentage improvement of the company's annual profit after being involved in R&D projects within the IRC	Quantitative
	Increased competitive standing of the organization in international markets	• The annual percentage improvement of the organization's share in the international market after being involved in R&D projects within the IRC	Quantitative
	Contributing to improved economic and social conditions for Canadians	• Level of effect of the organization's projects on improving economic and social conditions for Canadians after being involved in R&D projects within the IRC	Qualitative
	Enhancing the global competitiveness of the Canadian economy	• Level of effect of the organization's projects on enhancing the global competitiveness of the Canadian economy after being involved in R&D projects within the IRC	Qualitative
	Contributing to improved environmental conditions for Canadians	• Level of effect of the organization's practices on improving the environmental conditions for Canadians after being involved in R&D projects within the IRC	Qualitative
	Enhancing the organization's level of innovation	• Level of effect of the R&D projects within the IRC on enhancing the organization's level of innovation	Qualitative

A.9. Outcome criteria and corresponding metrics for the NSERC's role in the proposed submodel

Class of outcomes	Outcome criterion	Metric	Type of metric
Short-term Outcomes	Improved research quality of the IRC chairholder	• Level of improvement in the quality of the research conducted by the IRC chairholder	Qualitative
	Improved research quality of the university research team	• Level of improvement in the quality of the research conducted by the university research team for the IRC	Qualitative
	Improved industrial relevance of research	• Level of improvement in the industrial relevance of the research conducted by the university research team since the start of the IRC	Qualitative
	Improved knowledge and technologies in the relevant industrial area	• Level of improvement of the knowledge and technologies available to construction domain as a result of R&D projects within the IRC	Qualitative
	Increased pool of highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) with research expertise relevant to the industrial sector	• Level of increase in the HQP number with research expertise relevant to the construction domain as a result of R&D projects within the IRC	Qualitative
	Enhanced networks/partnerships (universities and industry partners)	• Level of enhancement in the collaboration and interaction between the IRC chairholder and other industrial partners outside the IRC • Number of existing industrial partners who extend and discontinue their participation in the IRC at each renewal • Number of new industrial partners who join the IRC at each renewal • Number of industrial partners outside the IRC in which the university research team collaborate with based on successful R&D projects within the IRC	Qualitative Quantitative Quantitative Quantitative
	Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	• Level of enhancement in collaboration and interaction between the IRC chairholder other colleagues in connection with the IRC program	Qualitative
	Increased university research capacity in an area directly related or complementary to the IRC	• Level of increase in the university's research capacity since the start of the IRC	Qualitative
Medium-term Outcomes	Enhanced use of research results by industrial partners (i.e., new and/or improved products and processes, policy development, etc.)	• Level of enhancement in utilizing research results by industrial partners after being involved in R&D projects within the IRC	Qualitative

Class of outcomes	Outcome criterion	Metric	Type of metric
	Transfer of knowledge and technologies to Canadian companies and government groups	• Frequency of transferring knowledge and technology into Canadian companies and government groups through R&D projects within the IRC	Qualitative
	Increase in evidence-based regulations and management practices	• Level of increase in the implementation of evidence-based regulations and management practices in the construction domain as a result of R&D projects	Qualitative
	Highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) obtain employment in their field of study and require less training once employed	• Level of agreement on the effect of R&D projects within the IRC on producing HQP that are well suited for employment at industrial partner organizations	Quantitative
Long-term Outcomes	Increased investment in R&D partnerships by the industrial sector	• The increase in the amount of funds in Canadian dollars invested by the industrial partners of IRC at each IRC renewal	Quantitative
	Stronger Canadian economy	• Level of effect of the IRC on strengthening the Canadian economy	Qualitative
	Enhanced economic and social benefits for Canadians	• Level of effect of the IRC on improving the economic and social conditions for Canadians	Qualitative
	Increased employment opportunities for highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writer, and Programmers) in natural sciences and engineering (NSE)	• Level of increase in employment opportunities for HQP from the IRC as result of R&D collaborations within the IRC	Qualitative
	Improved R&D performance by the Canadian construction industry	• Level of effect of R&D projects carried out through the IRC on improving the Canadian construction industry's R&D performance	Qualitative
	Contributing to improved environmental conditions for Canadians	• Level of effect of R&D projects carried out through the IRC on improving the environmental conditions for Canadians	Qualitative

APPENDIX B: EVALUATION QUESTIONNAIRES FOR DIFFERENT COLLABORATING PARTIES OF THE NSERC IRC

UNIVERSITY OF ALBERTA – NSERC INDUSTRIAL RESEARCH CHAIR (IRC) IN STRATEGIC CONSTRUCTION MODELING AND DELIVERY (SCMD)

A FRAMEWORK FOR EVALUATING THE IMPACT OF CONSTRUCTION RESEARCH AND DEVELOPMENT (R&D) ON UNIVERSITY, CONSTRUCTION INDUSTRY, AND GOVERNMENT

University (Chairholder & Researchers) – Questionnaire Survey

Thank you for agreeing to participate in this survey. We estimate that it will take ***thirty minutes*** to complete the questions.

YOUR RESPONSES IN THIS SURVEY WILL BE KEPT STRICTLY CONFIDENTIAL.

This questionnaire will be used by the NSERC Industrial Research Chair (IRC) in Strategic Construction Modeling and Delivery (SCMD) in the Department of Civil and Environmental Engineering at the University of Alberta, for evaluating and monitoring the progress of the IRC in SCMD. Your responses are important to the success of the study and any additional comments are welcomed. Please do not hesitate to ask the researcher for assistance should you have any questions.

INSTRUCTIONS

1. All questions should be answered by circling the appropriate choice or filling in the blank space provided. If a question is not applicable to your organization, please choose the N/A (not applicable) option from the responses. if you do not have sufficient information to answer a question, please choose Do not know option from the responses.
2. Answers should reflect your current status and knowledge. Do not refer to procedures or capabilities that are anticipated or proposed.
3. The questionnaire is divided into three main sections as follows: inputs, outputs, and outcomes. Each section is composed of subsections that represent the criteria to be evaluated. Each criterion is evaluated through a series of defined questions. Please respond to all questions and check **only one** of the choices if more than one choice is provided in a question, unless the question specifically indicates to choose **all that apply**.
4. The proposed outcomes are defined based on several studies that investigated the impact of R&D projects on university research teams collaborating on R&D projects. If a question is not applicable to you, please choose the N/A (not applicable) option from the responses.

Date completed (DD/MM/YYYY): ______________________________

Participant Information:

Name: ______________________________ Gender: __________________________

University: ___________________

Work address: __________________________ City: __________________

Province: ______________ Postal Code: _____________

Work phone: ________________ Work Fax: __________________

Work email: ___________________

Current position within the university research team:

☐ Chairholder ☐ Research associate ☐ Research fellow

☐ Postdoctoral fellow ☐ Research project leader ☐ Doctoral student

☐ Master's student ☐ Undergraduate student ☐ Technical writer

☐ Technician ☐ Management/administration

☐ Other (please specify): ___________________

You have been a member of the university research team for: ______ years _________ months

Your status on the university research team is: ☐Full-time ☐Part time

Education: Highest degree or level of schooling you have already completed.

☐ High school diploma or high school equivalency

☐ Technical, vocational, or trade school

☐ Community college diploma

☐ Bachelor's degree

☐ Master's degree

☐ Doctorate degree

☐ Other (please specify): _____________________________

Please specify any professional designation you currently hold: ____________________

Industrial Research Chair (IRC) Information:

Name of IRC: NSERC IRC in Strategic Construction Modeling and Delivery (SCMD)

Type of IRC: ☐ Senior ☐ Associate ☐Executive

Please specify the term of the IRC:

☐ First term ☐ Second term ☐ Third term ☐ Fourth term

☐ Greater than fourth term

Term of IRC:

Start date (DD/MM/YYYY): _____________ End date (DD/MM/YYYY): _____________

Please specify the timeframe in which you are evaluating this IRC:

☐ 0 to 18 months ☐ 18 to 36 months ☐ 36 to 48 months ☐ 48 to 60 months

☐ 0 to 60 months

SECTION I: INPUTS FOR R&D PARTNERSHIP

This section investigates investments in the R&D partnership such as funds, people, time, skills, and experience. The following list includes university-specific investments (i.e., inputs) in the R&D partnership considered for the purpose of this study: qualified research team involved in R&D projects, laboratories and facilities involved in R&D projects, industry connections facilitated by R&D collaborations, funding, trust in industrial partners working on R&D projects, time spent on R&D projects, previous R&D achievements, and teamwork effectiveness in R&D collaborations.

Section I.1: *Qualified research team involved in R&D projects:*

1.1. How many years of research experience do you have in total?
____________________ years __________________ months
or
☐ N/A ☐ Do not know

1.2. How many years of industry work experience do you have in total?
____________________ years __________________ months
or
☐ N/A ☐ Do not know

1.3. You understand the goals of the research carried out by the R&D team (i.e., team of university researchers and industry professionals) for the Industrial Research Chair (IRC) in Strategic Construction Modeling and Delivery (SCMD).
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.4. You have effective interactions with other members of the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.5. You apply your personal experience and observations to define different options and solve problems encountered by the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.6. You plan, implement, manage, and measure tasks in an efficient and timely manner within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.7. You take pride in your work within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.8. You strive for excellence so as to achieve the best possible results within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.9. You use sound judgment to meet or exceed team guidelines, standards, and expectations on R&D projects within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.10. You gain and apply new knowledge and skills within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

Section I.2: *Laboratories and facilities involved in R&D projects:*

1.11. How many laboratories and/or research spaces (i.e., offices) are used to carry out activities for R&D projects within the IRC in SCMD (including all members of the research team)?

___________laboratories ________ research spaces (offices)

or

☐ N/A ☐ Do not know

1.12. How do you evaluate the quality of laboratories and/or research spaces (i.e., offices) used for R&D projects within the IRC in SCMD?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section I.3: *Industry connections facilitated by R&D collaborations:*

1.13. Over the past _________, how many R&D industrial partners (construction organizations and/or government agencies other than NSERC) does the university research team have **within** the IRC in SCMD in total?

___________________ industrial partners and/or government agencies (other than NSERC)

or

☐ N/A ☐ Do not know

1.14. Over the past _________, how many of the aforementioned R&D industrial partners are owners and/or owner associations?

___________________ owners ___________________ owner associations

or

☐ N/A ☐ Do not know

1.15. Over the past _________, how many of the aforementioned R&D industrial partners are contractors and/or contractor associations?

___________________ contractors ___________________ contractor associations

or

☐ N/A ☐ Do not know

1.16. Over the past _________, how many of the aforementioned R&D industrial partners are labour groups?

___________________ labour groups

or

☐ N/A ☐ Do not know

1.17. Over the past _________, how many of the aforementioned R&D industrial partners are consultants?

___________________ consultants

or

☐ N/A ☐ Do not know

1.18. Over the past _________, how many of the aforementioned R&D industrial partners are government agencies (other than NSERC)?

___________________ government agencies (other than NSERC)

or

☐ N/A ☐ Do not know

1.19. Over the past _________, how many of the aforementioned R&D industrial partners are companies?

___________________ companies

or

☐ N/A ☐ Do not know

1.20. Over the past _________, how many of the aforementioned R&D industrial partners are associations?

___________________ associations

or

☐ N/A ☐ Do not know

1.21. Over the past _________, how many of the aforementioned R&D industrial partners are neither companies nor associations?

___________________ neither companies nor associations

or

☐ N/A ☐ Do not know

1.22. Over the past _________, how many R&D industrial partners (construction organizations and/or government agencies other than NSERC) does the university research team have **outside** of the IRC in SCMD in total?

___________________ industrial partners and/or government agencies other than NSERC

or

☐ N/A ☐ Do not know

Section I.4: <u>*Funding:*</u>

1.23. Annually, over the past _________, what is the total financial contribution of **all** industrial partners to the IRC in SCMD (not including NSERC's contribution)?

___________________ CAD/year

or

☐ N/A ☐ Do not know

1.24. Annually, over the past _________, what is the financial contribution of **each** industrial partner who is an **associate member** of the IRC in SCMD (not including NSERC's contribution)?

___________________ CAD/year

or

☐ N/A ☐ Do not know

1.25. Annually, over the past _________, what is the financial contribution of **each** industrial partner who is a **full member** of the IRC in SCMD (not including NSERC's contribution)?

___________________ CAD/year

or

☐ N/A ☐ Do not know

1.26. Annually, over the past _________, what is the financial contribution of **NSERC** to the IRC in SCMD?

___________________ CAD/year

or

☐ N/A ☐ Do not know

1.27. What types of in-kind contributions does the university research team receive from the industrial partners of the IRC in SCMD? Please choose ALL that apply:

☐ Personnel time (e.g., for meetings, data collection)

☐ Data (e.g., collected on site or from organization's personnel or records)

☐ Provision of office space and/or computer(s)

☐ Registrations/prizes/scholarships

☐ Training (e.g., safety training, specialized training, training in organization's systems)

☐ Travel/accommodation/meals

or

☐ N/A ☐ Do not know

1.28. Annually, over the past __________, what is the total in-kind contribution of **all** industrial partners to the IRC in SCMD ?

____________________ CAD/year

or

☐ N/A ☐ Do not know

1.29. Annually, over the past __________, what is the in-kind contribution of **each** industrial partner who is an **associate member** of the IRC in SCMD?

____________________ CAD/year

or

☐ N/A ☐ Do not know

1.30. Annually, over the past __________, what is the in-kind contribution of **each** industrial partner who is a **full member** of the IRC in SCMD?

____________________ CAD/year

or

☐ N/A ☐ Do not know

1.31. To what extent are you satisfied with the amount of remuneration you get for your work as a member of the university research team?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

1.32. To what extent are you satisfied with the financial contributions provided by the industrial partners to the IRC in SCMD?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

1.33. To what extent are you satisfied with the in-kind contributions provided by the industrial partners to the IRC in SCMD?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

1.34. To what extent are you satisfied with the financial contributions provided by NSERC to the IRC in SCMD?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

Section I.5: *Trust in industrial partners working on R&D projects:*

1.35. The industrial partners within the IRC in SCMD treat you in a way that is fair and just.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.36. The industrial partners within the IRC in SCMD take into consideration the objectives of the university research team whenever they make important decisions regarding R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.37. The behaviour of most of the industrial partners within the IRC in SCMD is guided by sound business principles.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.38. The industrial partners within the IRC in SCMD provide the university research team with accurate information, data, and facts.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.39. The industrial partners within the IRC in SCMD have strong research skills.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.40. The industrial partners within the IRC in SCMD are capable of completing required tasks related to industry participation in R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.41. The industrial partners within the IRC in SCMD are successful at completing required tasks related to industry participation in R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.42. The industrial partners within the IRC in SCMD uphold their commitments and keep their promises related to industry participation in R&D projects (i.e., providing adequate funding and in-kind contributions to carry out R&D projects, providing the university research team with access to technical data at their organizations, dedicating sufficient time to collaborate with university on R&D projects, etc.).

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.43. You allow the industrial partners within the IRC in SCMD to make decisions that may have a substantial impact on the planning and implementation of R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.44. The industrial partners within the IRC in SCMD will not take advantage of the university research team while working together on R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

Section I.6: *Time spent on R&D projects:*

1.45. Monthly, over the past _________, how much time in hours do you spend working on R&D projects within the IRC in SCMD?

___________________ hours/month
or
☐ N/A ☐ Do not know

Section I.7: <u>*Previous R&D achievements:*</u>

1.46. Over the past _________, how many R&D projects is the university research team working on with industrial partners of the IRC in SCMD?

___________________ R&D projects

or

☐ N/A ☐ Do not know

1.47. Over the past _________, how many R&D projects involving industrial partners of the IRC in SCMD have been completed on time?

___________________ R&D projects

or

☐ N/A ☐ Do not know

1.48. Over the past _________, how many R&D projects involving industrial partners of the IRC in SCMD have been completed on budget?

___________________ R&D projects

or

☐ N/A ☐ Do not know

Section I.8: <u>*Teamwork effectiveness in R&D collaborations:*</u>

1.49. You get along with the industry professionals within the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.50. You like the industry professionals within the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.51. You can work efficiently under stress with the industry professionals within the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.52. You are willing to share information with the industry professionals within the IRC in SCMD about the work done by the university research team (i.e., research results and findings).

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.53. You communicate well with the industry professionals within the IRC in SCMD when it comes to getting work done.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.54. You effectively provide support to industry professionals while working together in the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.55. Working in the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD has increased your opportunities for positive social interactions.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.56. You assist industry professionals within the IRC in SCMD in solving industrial problems when needed.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

SECTION 2: OUTPUTS OF R&D PARTNERSHIP

This section investigates the completed activities carried out through the R&D partnership and the people who are reached and impacted by their involvement such as clients, organizations, and decision makers. The following list includes university-specific activities (i.e., outputs) carried out through the R&D partnership considered for the purpose of this study: doing research in collaborative R&D teams, developing tools and solutions to problems through R&D projects, training industry professionals to enhance their performance and knowledge, publishing papers, technical reports, and newsletters, introducing presentations and posters at conferences and seminars, communicating R&D progress and results through the university research team's website, organizing workshops to present the results of R&D projects, and participating in advisory committee meetings of the IRC in SCMD.

The parties reached and impacted by the R&D partnership are as follows: university (i.e., the university research team), industrial partners of the IRC in SCMD, and government (i.e., NSERC).

Section II.1: *Doing research in collaborative R&D teams:*

2.1. How often does the research team carry out specific R&D projects in collaboration with industrial partners of the IRC in SCMD (e.g., labour productivity, competency, risk analysis, fuzzy arithmetic, etc.)?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.2. Annually, over the past _________, how many of the aforementioned R&D projects are basic (academic) research projects?

____________________ basic research projects/year

or

☐ N/A ☐ Do not know

2.3. Annually, over the past _________, how many of the aforementioned R&D projects are applied research projects?

____________________ applied research projects/year

or

☐ N/A ☐ Do not know

2.4. Annually, over the past _________, how many of the aforementioned R&D projects are both basic and applied research projects?

____________________ basic and applied research projects/year

or

☐ N/A ☐ Do not know

2.5. To what extent are you satisfied with the collaborative work done by the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD on R&D projects?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

2.6. To what extent are you satisfied with the internal collaboration on R&D projects between you and the rest of the university research team for the IRC in SCMD?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

2.7. To what extent are you satisfied with the external collaboration on R&D projects between you and industry professionals in the R&D team for the IRC in SCMD?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

2.8. Over the past _________, how long does it take for a PhD student to complete his or her degree within the university research team for the IRC in SCMD?

________________________ years ___________________________ months

or

☐ N/A ☐ Do not know

2.9. Over the past _________, how long does it take for an MSc student to complete his or her degree within the university research team for the IRC in SCMD?

________________________ years ___________________________ months

or

☐ N/A ☐ Do not know

2.10. Annually, over the past _________, how many of the graduate students within the university research team are posted at industrial partner organizations and/or job sites within the IRC in SCMD?

__________________ graduate students/year

or

☐ N/A ☐ Do not know

Section II.2: *Developing tools and solutions to problems through R&D projects:*

2.11. How often are the tools and solutions developed by the university research team through R&D projects successfully implemented with industrial partners of the IRC in SCMD?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.12. Annually, over the past _________, how many new software applications (i.e., data analysis programs) does the university research team develop through R&D projects within the IRC in SCMD?

__________________ software applications/year

or

☐ N/A ☐ Do not know

2.13. How do you evaluate the quality of the outcomes of R&D projects arising from the IRC in SCMD (e.g., new tools, new solutions to problems, new management skills, new practices, etc.)?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.3: *Training industry professionals to enhance their performance and knowledge:*

2.14. How often does the university research team provide training for industry professionals within the IRC in SCMD to enhance their performance and knowledge (e.g., an introduction to fuzzy logic, project management training, etc.)?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.15. Annually, over the past _________, how many training workshops does the university research team carry out for industrial partners within the IRC in SCMD?

__________________ training workshops/year

or

☐ N/A ☐ Do not know

2.16. Annually, over the past _________, how many industry professionals does the university research team train per training workshop organized by the IRC in SCMD?

___________________ trained industry professionals/training workshop

or

☐ N/A ☐ Do not know

2.17. To what extent are you satisfied with the outcomes of the training workshops provided by the university research team to industry professionals within the IRC in SCMD (i.e., improved practices, more effective working relationships, resolution of difficult or unfamiliar situations, improved productivity, etc.)?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

Section II.4: *Publishing papers, technical reports, newsletters, books, and manuals/guides:*

2.18. Annually, over the past _________, how many papers does the university research team publish in academic journals through R&D projects within the IRC in SCMD?

_________________ **journal** papers/year

or

☐ N/A ☐ Do not know

2.19. Annually, over the past _________, how many conference papers does the university research team publish through R&D projects within the IRC in SCMD?

_________________ **conference** papers/year

or

☐ N/A ☐ Do not know

2.20. Annually, over the past _________, how many technical reports are prepared by the university research team through R&D projects within the IRC in SCMD?

_________________ **technical** reports/year

or

☐ N/A ☐ Do not know

2.21. Annually, over the past _________, how many newsletters are prepared by the university research team through R&D projects within the IRC in SCMD?

__________________ **newsletters**/year

or

☐ N/A ☐ Do not know

2.22. Annually, over the past _________, how many books are prepared by the university research team through R&D projects within the IRC in SCMD?

__________________ **books**/year

or

☐ N/A ☐ Do not know

2.23. Annually, over the past _________, how many manuals/guides are prepared by the university research team through R&D projects within the IRC in SCMD?

__________________ **manuals/guides**/year

or

☐ N/A ☐ Do not know

2.24. Annually, over the past _________, how many other communication materials are prepared by the university research team through R&D projects within the IRC in SCMD?

__________________ **communication materials**/year

or

☐ N/A ☐ Do not know

2.25. How do you evaluate the quality of the different publications (e.g., journal papers, conference papers, technical reports, etc.) produced by the university research team through R&D projects within the IRC in SCMD?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.5: *Introducing presentations and posters at conferences and seminars:*

2.26. Annually, over the past _________, how many presentations does the university research team make in national, international, and industry conferences and seminars through R&D projects within the IRC in SCMD?

_________________ **presentations**/year

or

☐ N/A ☐ Do not know

2.27. Annually, over the past _________, how many posters does the university research team present in national, international, and industry conferences and seminars through R&D projects within the IRC in SCMD?

_________________ **research posters**/year

or

☐ N/A ☐ Do not know

2.28. How do you evaluate the quality of the presentations and research posters introduced by the university research team at conferences and seminars?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.6: *Communicating R&D progress and results through the university research team's website:*

2.29. How often does the university research team update information on the IRC in SCMD website regarding the progress of R&D projects carried out within the IRC in SCMD?

1- Monthly 2- Quarterly 3- Semi-annually 4- Annually 5- Longer than annually

or

☐ N/A ☐ Do not know

2.30. How do you evaluate the quality of the website content regarding the R&D projects carried out within the IRC in SCMD?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.7: *Organizing workshops to present the results of R&D projects:*

2.31. Annually, over the past _________, how many workshops does the university research team organize for the purpose of presenting the results and outcomes of R&D projects carried out within the IRC in SCMD (e.g., research results, software applications, etc.)?

_________________ organized workshops/year

or

☐ N/A ☐ Do not know

2.32. How do you evaluate the outcomes of the workshops organized by the university research team to present results of the R&D projects within the IRC in SCMD (i.e., providing opportunities to exchange information and knowledge, practicing communication skills, receiving feedback on the research work, developing skills of participants, involving participants in the learning process, etc.)?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.8: *Participating in advisory committee meetings of the IRC in SCMD:*

2.33. Annually, over the past _________, how many management advisory committee meetings does the chairholder of IRC in SCMD participate in?

____________________ management advisory committee meetings/year

or

☐ N/A ☐ Do not know

2.34. Annually, over the past _________, how many technical advisory committee meetings does the chairholder of IRC in SCMD participate in?

____________________ technical advisory committee meetings/year

or

☐ N/A ☐ Do not know

SECTION 3: OUTCOMES OF R&D PARTNERSHIP

This section investigates the expected outcomes and intended results of the R&D partnership; they are classified as either short-term, medium-term, or long-term outcomes.

A) **Short-term outcomes** are outcomes that directly result from outputs; examples include changes in skills (e.g., graduating highly experienced personnel), awareness (e.g., better understanding of industry needs; linking scientific theories with practical applications; and increased university research capacity in an area directly related or complementary to the IRC), knowledge (e.g., increasing the knowledge of researchers), and attitudes (e.g., fostering improved collaboration and stable relationships with industry; enhanced networks/partnerships (universities and industrial partners); and enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program), and aspirations (e.g., improving the reputation of researchers among peers; improved research quality of the university research team; improved industrial relevance of research; better development in the research facilities; and better development in the infrastructure).

Section III.1: *Graduating highly experienced personnel:*

3.1. To what extent do you think the experience of the university research team is increased by participating in R&D projects within the IRC in SCMD?

1-Very low 2- Low 3- Medium 4- High 5- Very high

or

☐ N/A ☐ Do not know

Section III.2: *Better understanding of industry needs:*

3.2. To what extent do you think the university research team has developed an improved awareness of industry needs after participating in R&D projects within the IRC in SCMD?

1- Not improved at all 2- Slightly improved 3- Somewhat improved
4- Very improved 5- Extremely improved
or
☐ N/A ☐ Do not know

Section III.3: *Linking scientific theories with practical applications:*

3.3. To what extent do you think R&D projects within the IRC in SCMD are aligned with practical industry needs?

1- Not aligned at all 2- Slightly aligned 3- Somewhat aligned 4- Very aligned
5- Extremely aligned
or
☐ N/A ☐ Do not know

Section III.4: *Increased university research capacity in an area directly related or complementary to the IRC:*

3.4. To what extent do you think the university's research capacity in the construction domain has increased since the start of the IRC in SCMD?

1-Very low 2-Low 3-Medium 4- High 5- Very high
or
☐ N/A ☐ Do not know

Section III.5: *Increasing the knowledge of researchers:*

3.5. To what extent do you think the knowledge and skills of the university research team are increased by participating in R&D projects within the IRC in SCMD?

1-Very low 2- Low 3- Medium 4- High 5- Very high
or
☐ N/A ☐ Do not know

Section III.6: *Fostering improved collaboration and stable relationships with industry:*

3.6. To what extent do you think that working together on different R&D projects has improved collaboration between the university research team and the industrial partners within the IRC in SCMD?

1- Not improved at all 2- Slightly improved 3- Somewhat improved
4- Very improved 5-Extremely improved
or
☐ N/A ☐ Do not know

Section III.7: *Enhanced networks/partnerships (universities and industrial partners):*

3.7. To what extent do you think that the collaboration and interaction between the IRC in SCMD chairholder and other industrial partners outside the IRC in SCMD have been enhanced in connection with the IRC program?

1- Not enhanced at all   2- Slightly enhanced   3- Somewhat enhanced
4- Very enhanced   5- Extremely enhanced
or
☐ N/A   ☐ Do not know

3.8. On average, at each IRC renewal, how many existing industrial partners extend their participation in the IRC in SCMD?

______________________ industrial partners/renewal
or
☐ N/A   ☐ Do not know

3.9. On average, at each IRC renewal, how many existing industrial partners discontinue their participation in the IRC in SCMD?

______________________ industrial partners/renewal
or
☐ N/A   ☐ Do not know

3.10. On average, at each IRC renewal, how many new industrial partners join the IRC in SCMD?

______________________ industrial partners/renewal
or
☐ N/A   ☐ Do not know

3.11. On average, over the past __________, how many industrial partners outside of the IRC program does the university research team collaborate with based on the successful R&D projects carried out within IRC in SCMD?

______________________ industrial partners
or
☐ N/A   ☐ Do not know

Section III.8: *Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program:*

3.12. To what extent do you think that the collaboration and interaction between the IRC in SCMD chairholder and other departmental and university colleagues have been enhanced in connection with the IRC program?

1- Not enhanced at all   2- Slightly enhanced   3- Somewhat enhanced
4- Very enhanced   5- Extremely enhanced
or
☐ N/A   ☐ Do not know

3.13. To what extent do you think that the collaboration and interaction between the IRC in SCMD chairholder and other colleagues from different academic institutions and research centres have been enhanced in connection with the IRC program?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced
4- Very enhanced 5- Extremely enhanced
or
☐ N/A ☐ Do not know

Section III.9: *Improving the reputation of researchers among their peers:*

3.14. To what extent do you think the reputation of the university research team has been enhanced by participating in R&D projects within the IRC in SCMD?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced
4- Very enhanced 5- Extremely enhanced
or
☐ N/A ☐ Do not know

3.15. As a member of the university research team, over the past _________, how many **regional** prizes and awards are won by you by participating in R&D projects within the IRC in SCMD?

___________________ best paper awards
___________________ individual and/or career achievement awards
___________________ group achievement awards
___________________ student scholarships and awards
_________________awarded honorary membership or a fellowship of a learned society
___________________ appointment as editor/advisor to a journal or book series
___________________ poster/abstract prize
___________________ honorary degree
___________________ chairs and/or professorships
or
☐ N/A ☐ Do not know

3.16. As a member of the university research team, over the past _________, how many **national** prizes and awards are won by you by participating in R&D projects within the IRC in SCMD?

___________________ best paper awards/year
___________________ individual and/or career achievement awards/year
___________________ group achievement awards/year
___________________ student scholarships and awards/year
_________________awarded honorary membership or a fellowship of a learned society/year
___________________ appointment as editor/advisor to a journal or book series/year
___________________ poster/abstract prize/year
___________________ honorary degree/year
___________________ chairs and/or professorships

or

☐ N/A ☐ Do not know

3.17. As a member of the university research team, over the past _________, how many **international** prizes and awards are won by you by participating in R&D projects within the IRC in SCMD?

___________________ best paper awards/year
___________________ individual and/or career achievement awards/year
___________________ group achievement awards/year
___________________ student scholarships and awards/year
_________________awarded honorary membership or a fellowship of a learned society/year
___________________ appointment as editor/advisor to a journal or book series/year
___________________ poster/abstract prize/year
___________________ honorary degree/year
___________________ chairs and/or professorships

or

☐ N/A ☐ Do not know

Section III.10: *Improved research quality of the university research team:*

3.18. To what extent do you think the quality of research conducted by the university research team has improved since the start of the IRC in SCMD?

1- Not improved at all 2- Slightly improved 3- Somewhat improved
4- Very improved 5- Extremely improved

or

☐ N/A ☐ Do not know

Section III.11: *Improved industrial relevance of research:*

3.19. To what extent do you think the industrial relevance of research conducted by the university research team has improved since the start of the IRC in SCMD?

1- Not improved at all 2- Slightly improved 3- Somewhat improved
4- Very improved 5- Extremely improved

or

☐ N/A ☐ Do not know

Section III.12: *Better development in the research facilities:*

3.20. What is the increase in the amount of funds invested in research facilities since the start of the IRC in SCMD?

_____________________ CAD

or

☐ N/A ☐ Do not know

Section III.13: *Better development in the infrastructure:*

3.21. What is the increase in the amount of funds invested in infrastructure since the start of the IRC in SCMD?

____________________ CAD

or

☐ N/A ☐ Do not know

B) Medium-term outcomes are outcomes that result from the application of short-term outcomes; examples include changes in actions (e.g., satisfying industry needs; creation of innovative technologies; and spin outs), reputations (e.g., enhanced academic reputation of the department and/or university), practices (e.g., enhanced feedback mechanisms for better communication and collaboration with industry; and expansion of the research program), management strategies (e.g., enhancement of the management system for R&D projects), and decisions (e.g., employment of highly qualified personnel (HQP)).

Section III.14: *Satisfying industry needs:*

3.22. To what extent do you think the needs of industry are satisfied by the results of the R&D projects carried out through the IRC in SCMD?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

Section III.15: *Creation of innovative technologies:*

3.23. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD have the potential to be **patented** based on your experience in the university research team?

_________________ products/5-year term

or

☐ N/A ☐ Do not know

3.24. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD have the potential to be **licensed** based on your experience in the university research team?

________________ products/5-year term

or

☐ N/A ☐ Do not know

3.25. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD are considered **innovative** based on your experience in the university research team?

__________________ products/5-year term

or

☐ N/A ☐ Do not know

3.26. On average, at the end of a 5-year term, how many processes (e.g., site management practices, human resource practices, procurement practices, new construction techniques, new modeling approaches, etc.) developed through R&D projects within the IRC in SCMD are considered **innovative** based on your experience in the university research team?

__________________ processes/5-year term

or

☐ N/A ☐ Do not know

3.27. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD are **transferred** to the industrial partners of the IRC in SCMD based on your experience in the university research team?

__________________ products/5-year term

or

☐ N/A ☐ Do not know

Section III.16: *Spin outs:*

3.28. As a chairholder of the IRC in SCMD, has your participation in R&D projects resulted in any spin outs?

☐Yes ☐No

If the answer is yes, please answer the rest of the questions in this section. Otherwise, please proceed to answer the questions in the following sections starting from section III.17.

3.29. Please enter the name of the company: ______________________________________

3.30. Please enter the registration number of the company:____________________________

3.31. When was the company established? ________________________________

3.32. Please enter the number of salaried people employees in this company: _______________

3.33. Please briefly describe the company:

____

____

____

3.34. Please briefly describe any notable impacts from this company:

____

____

____

____

3.35. Please enter the URL of this company (if applicable):

____

Section III.17: *Enhanced academic reputation of the department and/or university:*

3.36. To what extent do you think the reputation of the department and/or university has been enhanced by participating in R&D projects with the industrial partners within the IRC in SCMD?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced
4- Very enhanced 5- Extremely enhanced
or
☐ N/A ☐ Do not know

3.37. Annually, over the past _________, how many new PhD students are enrolled in the university research team for the IRC in SCMD?

_____________________ new PhD students/year
or
☐ N/A ☐ Do not know

3.38. Annually, over the past _________, how many new MSc students are enrolled in the university research team for the IRC in SCMD?

_____________________ new MSc students/year
or
☐ N/A ☐ Do not know

Section III.18: *Enhanced feedback mechanisms for better communication and collaboration with industry:*

3.39. To what extent do you think the quality of feedback mechanisms is enhanced after working together with industrial partners of the IRC in SCMD on different R&D projects (i.e., sharing feedback related to R&D projects with industrial partners, committee meetings and discussion groups regarding the progress of R&D projects, etc.)?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced
4- Very enhanced 5- Extremely enhanced
or
☐ N/A ☐ Do not know

Section III.19: *Expansion of the research program:*

3.40. To what extent do you think the research themes explored by the university research team have been diversified by working with industrial partners of the IRC in SCMD on R&D projects?

1-Very low 2-Low 3-Medium 4- High 5- Very high
or
☐ N/A ☐ Do not know

Section III.20: *Enhancement of the management system for R&D projects:*

3.41. To what extent do you think that working with industrial partners of the IRC in SCMD on different R&D projects has enhanced the quality of the university research team's management system for R&D projects (i.e., prioritizing project tasks, finishing projects on time and on budget, achieving project objectives, meeting or exceeding the expectations of industrial partners, etc.)?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced
4- Very enhanced 5- Extremely enhanced
or
☐ N/A ☐ Do not know

Section III.21: *Employment of highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers):*

3.42. Annually, over the past _________, how many members of the university research team are trained within the IRC in SCMD?

_____________________ undergraduate students/year
_____________________ masters students/year
_____________________ doctoral students/year
____________________ postdoctoral fellows/year
____________________ research associates/year
____________________ technical writers/year
____________________ programmers/year
or
☐ N/A ☐ Do not know

3.43. Annually, over the past _________, how many highly qualified personnel from the university research team are hired by industrial partners of the IRC in SCMD?

_____________________ undergraduate students/year
_____________________ masters students/year
_____________________ doctoral students/year
____________________ postdoctoral fellows/year
____________________ research associates/year
____________________ technical writers/year
____________________ programmers/year
or
☐ N/A ☐ Do not know

3.44. Annually, over the past _________, how many highly qualified personnel from the university research team for the IRC in SCMD are hired by other universities?

_____________________ undergraduate students/year
_____________________ masters students/year

______________________ doctoral students/year
_____________________ postdoctoral fellows/year
_____________________ research associates/year
_____________________ technical writers/year
_____________________ programmers/year
or
☐ N/A ☐ Do not know

C) <u>Long-term outcomes</u> are outcomes that result from the application of medium-term outcomes; examples include changes in scientific conditions (e.g., maintaining a leading position among top-ranked research universities all over the world; development of nationally and internationally-recognized expertise in various research areas; and enhancing Canada's level of technological innovation on a global scale), economic and social conditions (e.g., enhancing the global competitiveness of the Canadian economy; and contributing to improved economic and social conditions for Canadians), and environmental conditions (e.g., contributing to improved environmental conditions for Canadians).

Section III.22: *<u>Maintaining a leading position among top-ranked research universities all over the world:</u>*

3.45. Please indicate the current worldwide ranking of the Faculty of Engineering at your university according to QS World University Ranking System.

____
or
☐ N/A ☐ Do not know

Section III.23: *<u>Development of nationally and internationally-recognized expertise in various research areas:</u>*

3.46. To what extent do you think the research themes explored by the IRC in SCMD are influential in the construction domain on a national and international scale?
1-Not influential at all 2-Slightly influential 3-Somewhat influential
4-Very influential 5-Extremely influential
or
☐ N/A ☐ Do not know

Section III.24: *<u>Enhancing Canada's level of technological innovation on a global scale:</u>*

3.47. To what extent do you think the research themes explored by the IRC in SCMD are effective in terms of enhancing Canada's level of innovation on a global scale?
1-Not effective at all 2-Slightly effective 3-Somewhat effective

4-Very effective 5-Extremely effective
or
☐ N/A ☐ Do not know

Section III.25: *Enhancing the global competitiveness of the Canadian economy:*

3.48. To what extent do you think the research themes explored by the IRC in SCMD are effective in terms of enhancing the global competitiveness of the Canadian economy?
1-Not effective at all 2-Slightly effective 3-Somewhat effective
4-Very effective 5-Extremely effective
or
☐ N/A ☐ Do not know

Section III.26: *Contributing to improved economic and social conditions for Canadians:*

3.49. To what extent do you think the research themes explored by the IRC in SCMD are effective in terms of contributing to improved economic and social conditions for Canadians (i.e., enhanced income, improved productivity, higher employment rate, improved working conditions, etc.)?
1-Not effective at all 2-Slightly effective 3-Somewhat effective
4-Very effective 5-Extremely effective
or
☐ N/A ☐ Do not know

Section III.27: *Contributing to improved environmental conditions for Canadians:*

3.50. To what extent do you think the R&D projects carried out through the IRC in SCMD are effective in terms of contributing to improved environmental conditions for Canadians as a result of improved organizational practices, strategies, and management systems (i.e., efficient use of energy, water and other resources, etc.)?
1-Not effective at all 2-Slightly effective 3-Somewhat effective
4-Very effective 5-Extremely effective
or
☐ N/A ☐ Do not know

Thank you for completing the survey.

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UNIVERSITY OF ALBERTA – NSERC INDUSTRIAL RESEARCH CHAIR (IRC) IN STRATEGIC CONSTRUCTION MODELING AND DELIVERY (SCMD)

A FRAMEWORK FOR EVALUATING THE IMPACT OF CONSTRUCTION RESEARCH AND DEVELOPMENT (R&D) ON UNIVERSITY, CONSTRUCTION INDUSTRY, AND GOVERNMENT

Construction Organizations – Questionnaire Survey

Thank you for agreeing to participate in this survey. We estimate that it will take ***thirty minutes*** to complete the questions.

YOUR RESPONSES IN THIS SURVEY WILL BE KEPT STRICTLY CONFIDENTIAL.

This questionnaire will be used by the NSERC Industrial Research Chair (IRC) in Strategic Construction Modeling and Delivery (SCMD) in the Department of Civil and Environmental Engineering at the University of Alberta, for evaluating and monitoring the progress of the IRC in SCMD. Your responses are important to the success of the study and any additional comments are welcomed. Please do not hesitate to ask the researcher for assistance should you have any questions.

INSTRUCTIONS

1. All questions should be answered by circling the appropriate choice or filling in the blank space provided. If a question is not applicable to your organization, please choose the N/A (not applicable) option from the responses. if you do not have sufficient information to answer a question, please choose Do not know option from the responses.
2. Answers should reflect your current status and knowledge. Do not refer to procedures or capabilities that are anticipated or proposed.
3. The questionnaire is divided into three main sections as follows: inputs, outputs, and outcomes. Each section is composed of subsections that represent the criteria to be evaluated. Each criterion is evaluated through a series of defined questions. Please respond to all questions and check **only one** of the choices if more than one choice is provided in a question, unless the question specifically indicates to choose **all that apply**.
4. The proposed outcomes are defined based on several studies that investigated the impact of R&D projects on university research teams collaborating on R&D projects. If a question is not applicable to you, please choose the N/A (not applicable) option from the responses.

Date completed (DD/MM/YYYY): ______________________________

Respondent Information:

Name: ________________________________ Gender: ______________________

Organization Name: _______________ Organization Department: _________________

Job title: _____________________________

Work address: ___________________________ City: __________________

Province: ______________ Postal Code: _____________

Work phone: ________________ Work fax: __________________

Work email: _________________

Current position within the organization: _________________________________

You have been working at the organization for: ________years _________ months

Your status on the organization is: ☐Full-time ☐Part-time

Education: Highest degree or level of schooling you have completed.

☐ High school diploma or high school equivalency

☐ Technical, vocational, or trade school

☐ Community college diploma

☐ Bachelor's degree

☐ Master's degree

☐ Doctorate degree

☐ Other (please specify): ______________________________

Please specify any professional designation you currently hold: ____________________

Industrial Research Chair (IRC) Information:

Name of IRC: NSERC IRC in Strategic Construction Modeling and Delivery (SCMD)

Type of IRC: ☐ Senior ☐ Associate ☐ Executive

Please specify the term of the IRC:

☐ First term ☐ Second term ☐ Third term ☐ Fourth term

☐ Greater than fourth term

Term of IRC:

Start date (DD/MM/YYYY): _____________ End date (DD/MM/YYYY): _____________

Please specify the timeframe in which you are evaluating this IRC:

☐ 0 to 18 months ☐ 18 to 36 months ☐ 36 to 48 months ☐ 48 to 60 months

☐ 0 to 60 months

The organization has been a member of this IRC for: ______ years _________ months

You have been involved in this IRC for: ______ years _________ months

What is the membership type of the organization within the IRC in SCMD? Please choose from the following: ☐ Full member ☐ Associate member

Please state on which of the following advisory committees of this IRC you serve:

☐ Technical Advisory Committee ☐ Management Advisory Committee

☐ Both Advisory Committees ☐ Not a member of either Advisory Committee

Please select the industry of your organization: (please specify ALL that apply to your organization)

☐ New Home Building and Renovation – building, remodeling or renovating houses and apartment buildings.

☐ Civil Engineering Construction engineering projects – highways, dams, water and sewer lines, power and communications lines, and bridges

☐ Institutional and commercial construction – building commercial and institutional buildings and structures such as stadiums, schools, hospitals, grain elevators and indoor swimming pools

☐ Heavy Industrial facilities such as cement, automotive, chemical or power plants, refineries

and oil-sand installations.
☐ Other (please specify): ________________

SECTION 1: INPUTS FOR R&D PARTNERSHIP

This section investigates the investments in the R&D partnership such as funds, people, time, skills, and experience. The following list includes construction industry-specific investments (i.e., inputs) in the R&D partnership considered for the purpose of this study: organizational funding for R&D projects, in-kind contributions supplied by the organization to the university, qualified industry professionals involved in R&D projects, time spent on R&D projects, previous successful collaborative R&D projects, trust in academic partners working on R&D projects, teamwork effectiveness in R&D collaborations, access to technical data provided to the university research team, and university connections facilitated by R&D collaborations.

Section I.1: *Organizational funding for R&D projects:*

1.1. Annually, over the past _________, how much money does your organization invest in R&D projects within the IRC in SCMD?

____________________ CAD/year

or

☐ N/A ☐ Do not know

Section I.2: *In-kind contributions supplied by the organization to the university:*

1.2. What are the types of in-kind contributions does your organization provide to the university research team for the IRC in SCMD? Please choose all what is applicable from the following:

☐ Personnel time (e.g., for meetings, data collection)

☐ Data (e.g., collected on site or from organization's personnel or records)

☐ Provision of office space and/or computer(s)

☐ Registrations/prizes/scholarships

☐ Training (e.g., safety training, specialized training, training in organization's systems)

☐ Travel/accommodation/meals

or

☐ N/A ☐ Do not know

1.3. Annually, over the past _________, what are your organization's expenditures on in-kind contributions for R&D projects within the IRC in SCMD?

____________________ CAD/year

or

☐ N/A ☐ Do not know

Section I.3: *Qualified industry professionals involved in R&D projects:*

1.4. Annually, over the past _________, how many industry professionals from your organization are involved in R&D projects within the IRC in SCMD?

___________________ industry professionals/year

or

☐ N/A ☐ Do not know

1.5. How many years of industry work experience do you have in total?

___________________ years __________________ months

or

☐ N/A ☐ Do not know

1.6. How many years of research experience do you have in total?

__________________ years __________________ months

or

☐ N/A ☐ Do not know

1.7. You understand the goals of the research carried out by the R&D team (i.e., team of university researchers and industry professionals) for the Industrial Research Chair (IRC) in Strategic Construction Modeling and Delivery (SCMD).

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.8. You have effective interactions with other members of the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.9. You apply your personal experience and observations to define different options and solve problems encountered by the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.10. You plan, implement, manage, and measure tasks in an efficient and timely manner within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.11. You take pride in your work within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.12. You strive for excellence so as to achieve the best possible results within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.13. You use sound judgment to meet or exceed team guidelines, standards, and expectations on R&D projects within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.14. You gain and apply new knowledge and skills within the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

Section I.4: *Time spent on R&D projects:*

1.15. Monthly, over the past _________, how much time in hours do you spend working on R&D projects within the IRC in SCMD?

_____________________ hours/month

or

☐ N/A ☐ Do not know

Section I.5: *Previous successful collaborative R&D projects:*

1.16. Over the past _________, how many R&D projects is your organization working on with the university research team for the IRC in SCMD?

___________________ R&D projects

or

☐ N/A ☐ Do not know

1.17. Over the past _________, how many R&D projects involving the university research team for the IRC in SCMD have led to higher profits for your organization?

____________________ R&D projects

or

☐ N/A ☐ Do not know

1.18. Over the past _________, how many R&D projects involving the university research team for the IRC in SCMD have been completed on time?

____________________ R&D projects

or

☐ N/A ☐ Do not know

1.19. Over the past _________, how many R&D projects involving the university research team for the IRC in SCMD have been completed on budget?

____________________ R&D projects

or

☐ N/A ☐ Do not know

Section I.6: *Trust in academic partners working on R&D projects:*

1.20. The academic partner (i.e., the university research team) within the IRC in SCMD treats you in a way that is fair and just.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.21. The academic partner (i.e., the university research team) within the IRC in SCMD takes into consideration the objectives of your organization whenever they make important decisions regarding R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.22. The behaviour of the academic partner (i.e., the university research team) within the IRC in SCMD is guided by sound business principles.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.23. The academic partner (i.e., the university research team) within the IRC in SCMD provides your organization with accurate information, data, and facts.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.24. The academic partner (i.e., the university research team) within the IRC in SCMD has strong research skills.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.25. The academic partner (i.e., the university research team) within the IRC in SCMD is capable of completing required tasks related to academic participation in R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.26. The academic partner (i.e., the university research team) within the IRC in SCMD is successful at completing required tasks related to academic participation in R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.27. The academic partner (i.e., the university research team) within the IRC in SCMD upholds its commitments and keep its promises related to academic participation in the R&D projects (i.e., completing R&D projects on time, completing R&D projects on budget, dedicating sufficient time to work on R&D projects, using high quality laboratories in carrying out activities for R&D projects, etc.).

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.28. You allow the academic partner (i.e., the university research team) within the IRC in SCMD to make decisions that may have a substantial impact on the planning and implementation of R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

1.29. The academic partner (i.e., the university research team) within the IRC in SCMD will not take advantage of your organization while working together on R&D projects.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

Section I.7: *Teamwork effectiveness in R&D collaborations:*

1.30. You get along with the university researchers within the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or

☐ N/A ☐ Do not know

1.31. You like the university researchers within the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.32. You can work efficiently under stress with the university researchers within the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.33. You are willing to share information with the university researchers within the IRC in SCMD about organizational knowledge and data.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.34. You communicate well with the university researchers within the IRC in SCMD when it comes to getting work done.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.35. You effectively provide support to university researchers while working together in the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.36. Working in the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD has increased your opportunities for positive social interactions.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

1.37. You assist university researchers within the IRC in SCMD in solving specific research problems when needed.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

Section I.8: *Access to technical data provided to the university research team:*

1.38. Your organization provides the university research team for the IRC in SCMD with access to different technical data (i.e., reports, drawings, specifications, statistical data, etc.) and/or expert opinion and knowledge.

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree
4- Agree 5- Strongly agree
or
☐ N/A ☐ Do not know

Section I.9: *University connections facilitated by R&D collaborations:*

1.39. Over the past _________, how many R&D academic partners (i.e., university research teams) does your organization have **within** the IRC program in total, including the university research team for the IRC in SCMD?

__________________ academic partners
or
☐ N/A ☐ Do not know

1.40. Over the past _________, how many R&D academic partners (i.e., university research teams) does your organization have **outside** of the IRC program in total?

__________________ academic partners
or
☐ N/A ☐ Do not know

SECTION 2: OUTPUTS OF R&D PARTNERSHIP

This section investigates the completed activities carried out through the R&D partnership and the people who are reached and impacted by their involvement in the R&D partnership such as clients, organizations, and decision makers. The following list includes construction industry-specific activities (i.e., outputs) carried out through the R&D partnership considered for the purpose of this study: working with the university in the execution of R&D projects, assisting the university in the development of tools to address market needs, providing industry training to students by offering internships at the organization, providing technical support to the university research team on R&D projects, using university facilities and laboratories for the purpose of R&D projects, and participating in advisory committee meetings of the IRC in SCMD.

The parties reached and impacted by the R&D partnership are as follows: university (i.e., the university research team), the organization as an industrial partner of the IRC in SCMD, and government (i.e., NSERC).

Section II.1: *Working with the university in the execution of R&D projects:*

2.1. How often does your organization work with university to execute specific R&D projects within the IRC in SCMD (e.g., labour productivity, competency, risk analysis, fuzzy arithmetic, etc.)?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.2. Annually, over the past _________, how many of the aforementioned R&D projects are basic (academic) research projects?

___________________ basic research projects/year

or

☐ N/A ☐ Do not know

2.3. Annually, over the past _________, how many of the aforementioned R&D projects are applied research projects?

__________________ applied research projects/year

or

☐ N/A ☐ Do not know

2.4. Annually, over the past _________, how many of the aforementioned R&D projects are both basic and applied research projects?

____________________ basic and applied research projects/year

or

☐ N/A ☐ Do not know

2.5. To what extent are you satisfied with the collaborative work done by the R&D team (i.e., team of university researchers and industry professionals) of the IRC in SCMD on R&D projects?

1-Very dissatisfied 2-Dissatisfied 3-Unsure 4-Satisfied 5-Very satisfied

or

☐ N/A ☐ Do not know

2.6. To what extent are you satisfied with the collaboration on R&D projects between you and university researchers in the R&D team (i.e., team of university researchers and industry professionals) for the IRC in SCMD?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

2.7. Annually, over the past _________, how many of the graduate students within the university research team are posted at your organization and/or job sites within the IRC in SCMD?

_________________ graduate students/year

or

☐ N/A ☐ Do not know

Section II.2: *Assisting the university in the development of tools to address market needs:*

2.8. How often does your organization assist the university research team through R&D projects within the IRC in SCMD in the development of tools (i.e., software, databases, etc.) to address market needs?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.9. Annually, over the past _________, how many new software applications (i.e., data analysis programs) does your organization assist the university research team in developing through R&D projects within the IRC in SCMD?

_________________ software applications/year

or

☐ N/A ☐ Do not know

2.10. How do you evaluate the quality of the outcomes of R&D projects arising from the IRC in SCMD (e.g., new tools, new solutions to problems, new management skills, new practices, etc.)?

1-Poor 2-Fair 3-Good 4-Very good 5-Excellent

or

☐ N/A ☐ Do not know

Section II.3: *Providing industry training to graduate students by offering internships at the organization:*

2.11. How often does your organization provide training for graduate students within the IRC in SCMD through internships in your organization to enhance their performance and practical knowledge?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.12. Annually, over the past _________, how many internships does your organization provide for graduate students within the IRC in SCMD?

_____________________ internships/year

or

☐ N/A ☐ Do not know

2.13. Annually, over the past _________, how many graduate students does your organization train per internship within IRC in SCMD?

_____________________ trained graduate students/year

or

☐ N/A ☐ Do not know

2.14. To what extent are you satisfied with the outcomes of the internships provided by your organization to graduate students within the IRC in SCMD (i.e., students gain work experience and communication/interpersonal skills, students are able to experience toward their prospective career paths, students gain practical experience by applying methods and theories learned in the course of their studies and research work, students gain confidence in their abilities, etc.)?

1-Very dissatisfied 2-Dissatisfied 3-Unsure 4-Satisfied 5-Very satisfied

or

☐ N/A ☐ Do not know

Section II.4: *Providing technical support to the university research team on R&D projects:*

2.15. How often does your organization provide technical support (to the university research team for the IRC in SCMD (e.g., assigning organizational personnel to provide data and to assist in solving technical problems encountered during research, etc.)?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.16. How do you evaluate the quality of the technical data provided by your organization to the university research team for the purpose of R&D projects within the IRC in SCMD (i.e., reports, drawings, specifications, statistical data, and/or expert opinion and knowledge, etc.)?

1-Poor 2-Fair 3-Good 4-Very good 5-Excellent

or

☐ N/A ☐ Do not know

2.17. How do you evaluate the quality of the technical support provided by your organization to the university research team for solving technical problems encountered during the execution of the R&D projects within the IRC in SCMD?

1-Poor 2-Fair 3-Good 4-Very good 5-Excellent

or

☐ N/A ☐ Do not know

Section II.5: *Using university facilities and laboratories for the purpose of R&D projects:*

2.18. How often does your organization use university facilities and laboratories to carry out activities for R&D projects within the IRC in SCMD?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.19. How do you evaluate the quality of the university facilities and laboratories used by your organization to carry out activities for R&D projects within the IRC in SCMD?

1-Poor 2-Fair 3-Good 4-Very good 5-Excellent

or

☐ N/A ☐ Do not know

Section II.6: *Participating in advisory committee meetings of the IRC in SCMD:*

2.17. Annually, over the past _________, how many management advisory committee meetings does your organization participate in?

____________________ management advisory committee meetings/year

or

☐ N/A ☐ Do not know

2.18. Annually, over the past _________, how many technical advisory committee meetings does your organization participate in?

____________________ technical advisory committee meetings/year

or

☐ N/A ☐ Do not know

SECTION 3: OUTCOMES OF R&D PARTNERSHIP

This section investigates the expected outcomes and intended results of the R&D partnership; they are classified as either short-term, medium-term, or long-term outcomes.

A) **Short-term outcomes** are outcomes that result directly from outputs; examples include changes in attitudes (e.g., fostering improved collaboration with the university on R&D projects), skills (e.g., increasing the experience of employees), knowledge (e.g., increasing the knowledge of employees), aspirations (e.g., improving the organization's national competitive position among other organizations; improved research quality of the university research team; and improved industrial relevance of research), and awareness (e.g., better understanding of market needs).

Section III.1: *Fostering improved collaboration with the university on R&D projects:*

3.1. To what extent do you think that working together on different R&D projects has improved collaboration between your organization and the university research team for the IRC in SCMD?

1-Not improved at all 2-Slightly improved 3-Somewhat improved

4-Very improved 5-Extremely improved

or

☐ N/A ☐ Do not know

Section III.2: *Increasing the experience of employees:*

3.2. To what extent do you think the experience of the employees in your organization has been increased by participating in R&D projects within the IRC in SCMD?

1-Very low 2-Low 3-Medium 4-High 5-Very high

or

☐ N/A ☐ Do not know

Section III.3: *Increasing the knowledge of employees:*

3.3. To what extent of do you think the knowledge of the employees in your organization has been increased by participating in R&D projects within the IRC in SCMD?

1-Very low 2-Low 3-Medium 4-High 5-Very high

or

☐ N/A ☐ Do not know

Section III.4: *Improving the organization's national competitive position among other organizations:*

3.4. Please indicate the average annual percentage improvement of your organization's share in the domestic market over the past _________after being involved in R&D projects within the IRC in SCMD.

_________________ % /year

or

☐ N/A ☐ Do not know

Section III.5: *Improved research quality of the university research team:*

3.5. To what extent do you think the quality of research conducted by the university research team has improved since the start of the IRC in SCMD?

2- Not improved at all 2- Slightly improved 3- Somewhat improved

4- Very improved 5- Extremely improved

or

☐ N/A ☐ Do not know

Section III.6: *Improved industrial relevance of research:*

3.6. To what extent do you think the industrial relevance of research conducted by the university research team has improved since the start of the IRC in SCMD?

1- Not improved at all 2- Slightly improved 3- Somewhat improved

4- Very improved 5- Extremely improved

or

☐ N/A ☐ Do not know

Section III.7: ***Better understanding of market needs:***

3.7. To what extent do you think the employees in your organization have developed an improved awareness of the market needs after participating in R&D projects within the IRC in SCMD?

1-Not improved at all 2-Slightly improved 3-Somewhat improved
4-Very improved 5-Extremely improved
or
☐ N/A ☐ Do not know

B) Medium-term outcomes are outcomes that result from the application of short-term outcomes; examples include changes in decisions (e.g., hiring highly qualified personnel (HQP) to work at the organization), practices (e.g., enhanced feedback mechanisms for better communication and collaboration with the university on R&D projects), actions (e.g., changes in the organization's practices and strategies leading to improved industry performance; and sharing in the ownership of innovative results and products developed through R&D partnerships, and management strategies (e.g., enhancement of the management system for construction projects).

Section III.8: *Hiring highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) to work at the organization:*

3.8. Annually, over the past __________, how many HQP from the IRC in SCMD are hired by your organization?

______________________ undergraduate students/year
______________________ masters students/year
______________________ doctoral students/year
_____________________ postdoctoral fellows/year
_____________________ research associates/year
_____________________ technical writers/year
_____________________ programmers/year
or
☐ N/A ☐ Do not know

Section III.9: *Enhanced feedback mechanisms for better communication and collaboration with the university on R&D projects:*

3.9. To what extent do you think the quality of feedback mechanisms are enhanced after working together with the university research team on different R&D projects (i.e., sharing feedback related to R&D projects with academic partners, committee meetings and discussion groups regarding the progress of R&D projects, etc.)?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced
4- Very enhanced 5- Extremely enhanced

or

☐ N/A ☐ Do not know

Section III.10: *Changes in the organization's practices and strategies leading to improved industry performance:*

3.10. To what extent do you think your organization's practices and strategies have been improved as a result of involvement in R&D projects within the IRC in SCMD?

1-Not improved at all 2-Slightly improved 3-Somewhat improved
4-Very improved 5-Extremely improved

or

☐ N/A ☐ Do not know

3.11. To what extent do you think your organization's awareness of international construction standards has been improved as a result of involvement in R&D projects within the IRC in SCMD?

1-Not improved at all 2-Slightly improved 3-Somewhat improved
4-Very improved 5-Extremely improved

or

☐ N/A ☐ Do not know

Section III.11: *Sharing in the ownership of innovative results and products developed through R&D partnerships:*

3.12. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD have the potential to be **patented** based on your experience in the R&D team?

__________________ products/5-year term

or

☐ N/A ☐ Do not know

3.13. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD have the potential to be **licensed** based on your experience in the R&D team?

_________________ products/5-year term

or

☐ N/A ☐ Do not know

3.14. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD are considered **innovative** based on your experience in the R&D team?

__________________ products/5-year term

or

☐ N/A ☐ Do not know

3.15. On average, at the end of a 5-year term, how many processes (e.g., site management practices, human resource practices, procurement practices, new construction techniques, new modeling approaches, etc.) developed through R&D projects within the IRC in SCMD are considered **innovative** based on your experience in the R&D team?

__________________ processes/5-year term

or

☐ N/A ☐ Do not know

3.16. On average, at the end of a 5-year term, how many products (e.g., tools, software, databases, etc.) developed through R&D projects within the IRC in SCMD are **transferred** to your organization based on your experience in the R&D team?

__________________ products/5-year term

or

☐ N/A ☐ Do not know

Section III.12: *Enhancement of the management system for construction projects:*

3.17. To what extent do you think that working with the university research team for the IRC in SCMD on R&D projects has enhanced the quality of your organization's management system for construction projects (i.e., finishing construction projects on time and on budget, meeting or exceeding client expectations, etc.)?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced

4- Very enhanced 5- Extremely enhanced

or

☐ N/A ☐ Do not know

C) Long-term outcomes are outcomes that result from the application of medium-term outcomes; examples include changes in economic and social conditions (e.g., higher profits for the organization and better project and organizational performance; increased competitive standing of the organization in international markets; contributing to improved economic and social conditions for Canadians; and enhancing the global competitiveness of the Canadian economy), environmental conditions (e.g., contributing to improved environmental conditions for Canadians), and scientific conditions (e.g., enhancing the organization's level of innovation).

Section III.13: *<u>Higher profits for the organization and better project and organizational performance:</u>*

3.18. Please state the average annual reduction in the number of accidents over the past _________ at your organization after participating in R&D projects within the IRC in SCMD.

_____________ reduced accidents/year

or

☐ N/A ☐ Do not know

3.19. Please indicate the average annual percentage improvement of your organization's profit over the past _________after being involved in R&D projects within the IRC in SCMD.

_____________ %/year

or

☐ N/A ☐ Do not know

Section III.14: *<u>Increased competitive standing of the organization in international markets:</u>*

3.20. Please indicate the average annual percentage improvement of your organization's share in the international market over the past _________ after being involved in R&D projects within IRC in SCMD.

_____________ %/year

or

☐ N/A ☐ Do not know

Section III.15: *<u>Contributing to improved economic and social conditions for Canadians:</u>*

3.21. Assuming that your involvement in R&D projects within the IRC in SCMD has positively impacted your organization's practices, strategies, and management systems, to what extent do you think that your organization's projects are effective in terms of contributing to improved economic and social conditions for Canadians (i.e., enhanced income, improved productivity, higher employment rate, improved working conditions, etc.)?

1-Not effective at all 2-Slightly effective 3-Somewhat effective

4-Very effective 5-Extremely effective

or

☐ N/A ☐ Do not know

Section III.16: *<u>Enhancing the global competitiveness of the Canadian economy:</u>*

3.22. Assuming that your involvement in R&D projects within the IRC in SCMD has positively impacted your organization's practices, strategies, and management systems, to what extent do you think that your organization's projects are effective in terms of enhancing the global competitiveness of the Canadian economy?

1-Not effective at all 2-Slightly effective 3-Somewhat effective

4-Very effective 5-Extremely effective

or

☐ N/A ☐ Do not know

Section III.17: *Contributing to improved environmental conditions for Canadians:*

3.23. Assuming that your involvement in R&D projects within the IRC in SCMD has positively impacted your organization's practices, strategies, and management systems, to what extent do you think that your organization's practices are effective in terms of contributing to improved environmental conditions for Canadians (i.e., efficient use of energy, water and other resources, etc.)?

1-Not effective at all 2-Slightly effective 3-Somewhat effective
4-Very effective 5-Extremely effective

or

☐ N/A ☐ Do not know

Section III.18: *Enhancing the organization's level of innovation:*

3.24. To what extent do you think the R&D projects within the IRC in SCMD are effective in terms of enhancing your organization's level of innovation?

1-Not effective at all 2-Slightly effective 3-Somewhat effective
4-Very effective 5-Extremely effective

or

☐ N/A ☐ Do not know

Thank you for completing the survey.

UNIVERSITY OF ALBERTA – NSERC INDUSTRIAL RESEARCH CHAIR (IRC) IN STRATEGIC CONSTRUCTION MODELING AND DELIVERY (SCMD)

A FRAMEWORK FOR EVALUATING THE IMPACT OF CONSTRUCTION RESEARCH AND DEVELOPMENT (R&D) ON UNIVERSITY, CONSTRUCTION INDUSTRY, AND GOVERNMENT

Natural Sciences and Engineering Research Council of Canada (NSERC) / Industrial Research Chair Program (IRC) – Questionnaire Survey

Thank you for agreeing to participate in this survey. We estimate that it will take ***thirty minutes*** to complete the questions.

YOUR RESPONSES IN THIS SURVEY WILL BE KEPT STRICTLY CONFIDENTIAL.

This questionnaire will be used by the NSERC Industrial Research Chair (IRC) in Strategic Construction Modeling and Delivery (SCMD) in the Department of Civil and Environmental Engineering at the University of Alberta, for evaluating and monitoring the progress of the IRC in SCMD. Your responses are important to the success of the study and any additional comments are welcomed. Please do not hesitate to ask the researcher for assistance should you have any questions.

INSTRUCTIONS

1. All questions should be answered by circling the appropriate choice or filling in the blank space provided. If a question is not applicable to your organization, please choose the N/A (not applicable) option from the responses. if you do not have sufficient information to answer a question, please choose Do not know option from the responses.
2. Answers should reflect your current status and knowledge. Do not refer to procedures or capabilities that are anticipated or proposed.
3. The questionnaire is divided into three main sections as follows: inputs, outputs, and outcomes. Each section is composed of subsections that represent the criteria to be evaluated. Each criterion is evaluated through a series of defined questions. Please respond to all questions and check **only one** of the choices if more than one choice is provided in a question, unless the question specifically indicates to choose **all that apply**.
4. The proposed outcomes are defined based on several studies that investigated the impact of R&D projects on university research teams collaborating on R&D projects. If a question is not applicable to you, please choose the N/A (not applicable) option from the responses.

Date completed (DD/MM/YYYY): ________________________________

Respondent Information:

Name: ________________________________ Gender: ______________________

Job title: _____________________________ NSERC Division: _________________

Work address: ___________________________ City: __________________

Province: ______________ Postal Code: _____________

Work phone: ________________ Work Fax: __________________

Work email: ___________________

Current position within NSERC: _________________________________

You have been working at NSERC for: ________years _________ months

Your working status at NSERC is: ☐ Full-time ☐ Part-time

Education: Highest degree or level of schooling you have completed.

☐ High school diploma or high school equivalency

☐ Technical, vocational, or trade school

☐ Community college diploma

☐ Bachelor's degree

☐ Master's degree

☐ Doctorate degree

☐ Other (please specify): ______________________________

Please specify any professional designation you currently hold: ____________________

Industrial Research Chair (IRC) Information:

Name of IRC: NSERC IRC in Strategic Construction Modeling and Delivery (SCMD)

Type of IRC: ☐ Senior ☐ Associate ☐ Executive

Please specify the term of the IRC:

☐ First term ☐ Second term ☐ Third term ☐ Fourth term

☐ Greater than fourth term

Term of IRC:

Start date (DD/MM/YYYY): _____________ End date (DD/MM/YYYY): _____________

Please specify the timeframe in which you are evaluating this IRC:

☐ 0 to 18 months ☐ 18 to 36 months ☐ 36 to 48 months ☐ 48 to 60 months

☐ 0 to 60 months

You have been involved in this chair for: ________years _________ months

SECTION 1: INPUTS FOR R&D PARTNERSHIP

This section investigates investments in the R&D partnership such as funds, people, time, skills, and experience. The following list includes investments (i.e., inputs) that are specific to NSERC considered for the purpose of this study: qualified personnel involved in R&D partnerships, funding of different chairs in the IRC program, time spent on R&D projects, previous R&D achievements, existing management tools and systems, existing partnerships, knowledge of market and government needs.

Section I.1: *Qualified personnel involved in R&D partnerships:*

1.1. How many years of experience do you have working at NSERC?
_______________ years _________________ months
or
☐ N/A ☐ Do not know

1.2. How many years of experience do you have working with the IRC in SCMD specifically?
_______________ years _________________ months
or
☐ N/A ☐ Do not know

1.3. You understand the goals of the IRC in SCMD as a component of the IRC program.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.4. You have effective interactionswith the partners (i.e., university and industry) of the IRC in SCMD.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.5. You plan, implement, manage, and measure tasks (e.g., review proposals, prepare reports, etc.) in an efficient and timely manner within the IRC in SCMD.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.6. You take pride in your work within the IRC in SCMD.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.7. You strive for excellence so as to achieve the best possible results for the IRC in SCMD.
1- Never 2- Rarely 3- Sometimes 4- Often 5- Always
or
☐ N/A ☐ Do not know

1.8. You use sound judgment to meet or exceed the guidelines, standards, and expectations of the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

1.9. You gain and apply new knowledge and skills within the IRC in SCMD.

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

Section I.2: *Funding of different chairs in the IRC program:*

1.10. Annually, over the past _________, how much money does NSERC invest in R&D projects within the IRC program (in general)?

____________________ CAD/year

or

☐ N/A ☐ Do not know

Section I.3: *Time spent on R&D projects:*

1.11. Monthly, over the past _________, how much time in hours do you spend on activities related to R&D projects within the IRC in SCMD?

___________________ hours/month

or

☐ N/A ☐ Do not know

Section I.4: *Previous R&D achievements:*

1.12. Over the past _________, how many R&D projects within IRC program (in general) have been completed on time?

_______________ R&D projects

or

☐ N/A ☐ Do not know

1.13. Over the past _________, how many R&D projects within IRC program (in general) have been completed on budget?

_______________ R&D projects

or

☐ N/A ☐ Do not know

1.14. How many IRCs have been awarded by NSERC since the beginning of the IRC program?

___________________ chairs

or

☐ N/A ☐ Do not know

Section I.5: <u>*Existing management tools and systems:*</u>

1.15. How do you evaluate the quality of the existing management tools and systems used by NSERC for the purpose of managing, supervising, and evaluating the IRC in SCMD?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section I.6: <u>*Existing partnerships:*</u>

1.16. Annually, over the past _________, how many industrial partners within the IRC program (in general) does NSERC have?

_______________________ industrial partners/year

or

☐ N/A ☐ Do not know

1.17. Annually, over the past _________, how many academic partners within the IRC program (in general) does NSERC have?

_______________________ academic partners/year

or

☐ N/A ☐ Do not know

Section I.7: <u>*Knowledge of market and government needs:*</u>

1.18. To what extent do you think the IRC in SCMD is aware of market and government needs?

1- Not aware at all 2- Slightly aware 3- Somewhat aware
4- Very aware 5- Extremely aware

or

☐ N/A ☐ Do not know

SECTION 2: OUTPUTS OF R&D PARTNERSHIP

This section investigates the completed activities carried out through the R&D partnership, and the people who are reached and impacted by their involvement such as clients, organizations, and decision makers. The following list includes activities (i.e., outputs) carried out by NSERC through the R&D partnership considered for the purpose of this study: linking industry with university through R&D collaborations, attracting highly qualified personnel (HQP) to work on different R&D projects, publishing of communication materials (i.e., guides, reports, announcements, etc.), updating information on NSERC website, review and selection of applications for IRC funding, administration and management of grants and the renewal process, evaluation of progress reports from chairholders, providing feedback on chairholders progress reports, and providing training workshops for university and industry groups.

The parties reached and impacted by the R&D partnership are as follows: university (i.e., the university research team), industrial partners of the IRC in SCMD, and government (i.e., NSERC).

Section II.1: *Linking industry with university through R&D collaborations:*

2.1. How often does NSERC link its industrial partners with the university research team through the IRC in SCMD to collaborate on R&D projects?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.2. Annually, over the past _________, how many of the aforementioned R&D projects are basic (academic) research projects?

________________ basic research projects/year

or

☐ N/A ☐ Do not know

2.3. Annually, over the past _________, how many of the aforementioned R&D projects are applied research projects?

________________ applied research projects/year

or

☐ N/A ☐ Do not know

2.4. Annually, over the past _________, how many of the aforementioned R&D projects are both basic and applied research projects?

____________________ basic and applied research projects/year

or

☐ N/A ☐ Do not know

2.5. To what extent are you satisfied with the collaborative work done by NSERC with partners of IRC in SCMD (i.e., university and industry)?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

Section II.2: *Attracting highly qualified personnel (HQP) (i.e., Masters Students, and Doctoral Students) to work on different R&D projects:*

2.6. How often does NSERC attract HQP to work on R&D projects via the IRC in SCMD by supporting them financially?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.7. Annually, over the past _________, how many scholarships does NSERC offer for doctoral students within the IRC in SCMD?

______________________ scholarships/year

or

☐ N/A ☐ Do not know

2.8. Annually, over the past __________, how many scholarships does NSERC offer for masters students within the IRC in SCMD?

______________________ scholarships/year

or

☐ N/A ☐ Do not know

2.9. Annually, over the past __________, what is the value of scholarship offered to doctoral students within the IRC in SCMD?

______________________ CAD/year

or

☐ N/A ☐ Do not know

2.10. Annually, over the past __________, what is the value of scholarship offered to masters students within the IRC in SCMD?

_____________________ CAD/year

or

☐ N/A ☐ Do not know

2.11. How do you evaluate the quality of the personnel hired (i.e., graduate students and postdoctoral fellows) by the chairholder of IRC in SCMD to work on different R&D projects?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.3: *Publishing of communication materials (i.e., guides, reports, announcements, etc.):*

2.12. How often does NSERC publish communication materials (i.e., guides, reports, announcements, etc.) for the IRC program (in general)?

1- Monthly 2- Quarterly 3- Semi-annually 4- Annually 5- Longer than annually

or

☐ N/A ☐ Do not know

2.13. How do you evaluate the quality of the different publications (e.g., guides, reports, announcements, etc.) produced by NSERC?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.4: *Updating information on NSERC website:*

2.14. How often does NSRC update information on its website regarding awards, grants, scholarships, and university-industry collaborations related to the IRC program (in general)?

1- Monthly 2- Quarterly 3- Semi-annually 4- Annually 5- Longer than annually

or

☐ N/A ☐ Do not know

2.15. How do you evaluate the quality of the website content regarding awards, grants, scholarships, and university-industry collaborations related to the IRC program (in general)?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.5: *Review and selection of applications for IRC funding:*

2.16. Annually, over the past _________, how many proposals for IRC funding does NSERC receive?

___________________ proposal/year

or

☐ N/A ☐ Do not know

2.17. Annually, over the past _________, what is the acceptance rate of proposals submitted for IRC funding?

___________________ %/year

or

☐ N/A ☐ Do not know

Section II.6: *Administration and management of grants and the renewal process:*

2.18. Annually, over the past _________, how many IRC chairholders does NSERC fund?

____________________ IRC chairholders/year

or

☐ N/A ☐ Do not know

2.19. Annually, over the past _________, what level of funding does NSERC provide for the IRC in SCMD?

____________________ CAD/year

or

☐ N/A ☐ Do not know

Section II.7: *Evaluation of progress reports from chairholders:*

2.20. How often does your organization evaluate the progress reports from the IRC in SCMD? Please tick all applicable reporting periods:

☐ 18 months ☐ 36 months ☐ 48 months ☐ 52 months

or

☐ N/A ☐ Do not know

2.21. To what extent do you agree that the objectives of the IRC in SCMD have been clearly presented in their progress reports?

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

2.22. Based on the content of previous progress reports, to what extent do you agree that the IRC in SCMD has made progress towards achieving their defined objectives?

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

2.23. How often does the IRC in SCMD make deviations from their originally defined objectives in their progress reports?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.24. How do you think that deviations from originally defined objectives impact the progress of the IRC in SCMD?

1-Very negative 2-Negavtive 3-Neither negative nor positive 4-Positive 5-Very positive

or

☐ N/A ☐ Do not know

2.25. What are the main types of problems that your organization faces in evaluating the IRC in SCMD? Please tick all applicable options from the following list:

☐ Time ☐ Funds ☐ Staffing ☐ Other (specify):___________________________

Or

☐ No problems have been faced in evaluating the IRC in SCMD

or

☐ N/A ☐ Do not know

2.26. If applicable, how often does your organization face these types of problems in evaluating the IRC in SCMD?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

Section II.8: *Providing feedback on progress reports from chairholders:*

2.27. How often does your organization provide feedback on the progress reports submitted by the IRC in SCMD?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

2.28. How do you evaluate the overall quality of the progress reports submitted by the IRC in SCMD?

1- Poor 2- Fair 3- Good 4- Very good 5- Excellent

or

☐ N/A ☐ Do not know

Section II.9: <u>*Providing training workshops for university and industry groups:*</u>

2.29. Annually, over the past _________, how many training workshops does NSERC organize to support the university's research team within the IRC in SCMD?

______________________ training workshops/year

or

☐ N/A ☐ Do not know

2.30. Annually, over the past _________, how many training workshops does NSERC organize to support the industrial partners within the IRC in SCMD?

______________________ training workshops/year

or

☐ N/A ☐ Do not know

2.31. Over the past _________, how many university researchers within the IRC in SCMD does your organization train per workshop?

______________________ university researchers/training workshop

or

☐ N/A ☐ Do not know

2.32. Over the past _________, how many industry professionals within the IRC in SCMD does your organization train per workshop?

_____________________ industry professionals/training workshop

or

☐ N/A ☐ Do not know

2.33. To what extent are you satisfied with the outcomes of the training workshops provided by NSERC to university's researchers within the IRC in SCMD (i.e., improved practices, more effective working relationships, resolution of difficult or unfamiliar situations, improved productivity, etc.)?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

2.34. To what extent are you satisfied with the outcomes of the training workshops provided by NSERC to the industry professionals within the IRC in SCMD (i.e., improved practices, more effective working relationships, resolution of difficult or unfamiliar situations, improved productivity, etc.)?

1- Very dissatisfied 2- Dissatisfied 3- Unsure 4- Satisfied 5- Very satisfied

or

☐ N/A ☐ Do not know

SECTION 3: OUTCOMES OF R&D PARTNERSHIP

This section investigates the end results and products of the R&D partnership; they are classified as either short-term, medium-term, or long-term outcomes.

A) Short-term outcomes are outcomes that directly result from outputs; examples include changes in aspirations (e.g., improved research quality of the IRC chairholders; improved research quality of the university research team; and improved industrial relevance of research), knowledge (e.g., improved knowledge and technologies in the relevant industrial area), skills (e.g., increased pool of highly qualified personnel (HQP) with research expertise relevant to the industrial sector), attitudes (e.g., enhanced networks/partnerships (universities and industry partners); and enhanced collaborations and interaction between the chairholders and other colleagues in connection with the IRC program), and awareness (e.g., increased university research capacity in an area directly related or complementary to the IRC).

Section III.1: *Improved research quality of the IRC chairholder:*

3.1. To what extent do you think the quality of research conducted by the IRC in SCMD has been improving over time?

1-Not improved at all 2-Slightly improved 3-Somewhat improved

4-Very improved 5-Extremely improved

or

☐ N/A ☐ Do not know

Section III.2: *Improved research quality of the university research team:*

3.2. To what extent do you think the quality of research conducted by the university research team has improved since the start of the IRC in SCMD?

3- Not improved at all 2- Slightly improved 3- Somewhat improved

4- Very improved 5- Extremely improved

or

☐ N/A ☐ Do not know

Section III.3: *Improved industrial relevance of research:*

3.3. To what extent do you think the industrial relevance of research conducted by the university research team has improved since the start of the IRC in SCMD?

1- Not improved at all 2- Slightly improved 3- Somewhat improved

4- Very improved 5- Extremely improved

or

☐ N/A ☐ Do not know

Section III.4: *Improved knowledge and technologies in the relevant industrial area:*

3.4. To what extent do you think the knowledge and technologies available to construction domain have been improved as a result of R&D projects within the IRC in SCMD?

1-Not improved at all 2- Slightly improved 3- Somewhat improved

4- Very improved 5- Extremely improved

or

☐ N/A ☐ Do not know

Section III.5: <u>*Increased pool of highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) with research expertise relevant to the industrial sector:*</u>

3.5. To what extent do you think that the number of HQP with research expertise relevant to the construction domain has increased as a result of R&D projects within the IRC in SCMD?

1-Very low 2- Low 3- Medium 4- High 5- Very high

or

☐ N/A ☐ Do not know

Section III.6: <u>*Enhanced networks/partnerships (universities and industry partners):*</u>

3.6. To what extent do you think that the collaboration and interaction between the IRC in SCMD chairholder and other industrial partners outside the IRC in SCMD have been enhanced in connection with the IRC program?

1- Not enhanced at all 2- Slightly enhanced 3- Somewhat enhanced

4- Very enhanced 5- Extremely enhanced

or

☐ N/A ☐ Do not know

3.7. On average, at each IRC renewal, how many existing industrial partners extend their participation in the IRC in SCMD?

______________________ industrial partners/renewal

or

☐ N/A ☐ Do not know

3.8. On average, at each IRC renewal, how many existing industrial partners discontinue their participation in the IRC in SCMD?

______________________ industrial partners/renewal

or

☐ N/A ☐ Do not know

3.9. On average, at each IRC renewal, how many new industrial partners join the IRC in SCMD?

______________________ industrial partners/renewal

or

☐ N/A ☐ Do not know

Section III.7: *Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program:*

3.10. To what extent do you think that the collaboration and interaction between the IRC in SCMD chairholder and other departmental and university colleagues have been enhanced in connection with the IRC program?

1- Not enhanced at all   2- Slightly enhanced   3- Somewhat enhanced
4- Very enhanced   5- Extremely enhanced
or
☐ N/A   ☐ Do not know

3.11. To what extent do you think that the collaboration and interaction between the IRC in SCMD chairholder and other colleagues from different academic institutions and research centres have been enhanced in connection with the IRC program?

1- Not enhanced at all   2- Slightly enhanced   3- Somewhat enhanced
4- Very enhanced   5- Extremely enhanced
or
☐ N/A   ☐ Do not know

Section III.8: *Increased university research capacity in an area directly related or complementary to the IRC:*

3.12. To what extent do you think the university's research capacity in the construction domain has been increased as a result of R&D projects within the IRC in SCMD?

1-Very low   2- Low   3- Medium   4- High   5- Very high
or
☐ N/A   ☐ Do not know

B) Medium-term outcomes are outcomes that result from the application of short-term outcomes; examples include changes in actions (e.g., enhanced use of research results by industrial partners (i.e., new and/or improved products and processes, policy development, etc.); and transfer of knowledge and technologies to Canadian companies and government groups), management strategies (e.g., increase in evidence-based regulations and management practices), and decisions (e.g., highly qualified personnel (HQP) obtain employment in their field of study and require less training once employed).

Section III.9: *Enhanced use of research results by industrial partners (i.e., new and/or improved products and processes, policy development, etc.):*

3.13. To what extent do you think the level at which industrial partners utilize research results has been enhanced after being involved in R&D projects within the IRC in SCMD?

1- Not enhanced at all   2- Slightly enhanced   3- Somewhat enhanced
4- Very enhanced   5- Extremely enhanced

or

☐ N/A ☐ Do not know

Section III.10: *Transfer of knowledge and technologies to Canadian companies and government groups:*

3.14. How often are new technologies and knowledge transferred into Canadian companies and government groups through R&D projects within the IRC in SCMD?

1- Never 2- Rarely 3- Sometimes 4- Often 5- Always

or

☐ N/A ☐ Do not know

Section III.11: *Increase in evidence-based regulations and management practices:*

3.15. To what extent do you think that the implementation of evidence-based regulations and management practices in the construction domain has been increasing as a result of R&D projects within the IRC in SCMD?

1-Very low 2- Low 3- Medium 4- High 5- Very high

or

☐ N/A ☐ Do not know

Section III.12: *Highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers) obtain employment in their field of study and require less training once employed:*

3.16. To what extent do you agree that participation in R&D projects within the IRC in SCMD produces HQP (highly qualified personnel) that are well suited for employment at industrial partner organizations and that will also require less training once employed?

1- Strongly disagree 2- Disagree 3- Neither agree nor disagree

4- Agree 5- Strongly agree

or

☐ N/A ☐ Do not know

C) Long-term outcomes are outcomes that result from the application of medium-term outcomes; examples include changes in economic and social conditions (e.g., increased investment in R&D partnerships by the industrial sector, stronger Canadian economy; enhanced economic and social benefits for Canadians; and increased employment opportunities for highly qualified personnel (HQP) in the natural sciences and engineering (NSE)), scientific conditions (e.g., improved R&D performance by the Canadian construction industry), and environmental conditions (e.g., contributing to improved environmental conditions for Canadians).

Section III.13: *Increased investment in R&D partnerships by the industrial sector:*

3.17. On average, at each IRC renewal, what is the increase in the amount of funds invested by the industrial partners of IRC in SCMD in R&D projects?

_____________________ CAD/renewal

or

☐ N/A ☐ Do not know

Section III.14: *Stronger Canadian economy:*

3.18. To what extent do you think the IRC in SCMD is effective in terms of contributing to the strength of the Canadian economy?

1-Not effective at all 2-Slightly effective 3-Somewhat effective

4-Very effective 5-Extremely effective

or

☐ N/A ☐ Do not know

Section III.15: *Enhanced economic and social benefits for Canadians:*

3.19. To what extent do you think the IRC in SCMD is effective in terms of enhancing the economic and social conditions for Canadians (i.e., enhanced income, improved productivity, higher employment rate, improved working conditions, etc.)?

1-Not effective at all 2-Slightly effective 3-Somewhat effective

4-Very effective 5-Extremely effective

or

☐ N/A ☐ Do not know

Section III.16: *Increased employment opportunities for highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writer, and Programmers) in natural sciences and engineering (NSE):*

3.20. To what extent do you think that R&D collaborations within the IRC in SCMD have contributed to increased employment opportunities for HQP from the IRC in SCMD?

1-Very low 2- Low 3- Medium 4- High 5- Very high

or

☐ N/A ☐ Do not know

Section III.17: *Improved R&D performance by the Canadian construction industry:*

3.21. To what extent do you think the R&D projects carried out through the IRC in SCMD are effective in terms of improving the Canadian construction industry's R&D performance?

1-Not effective at all 2-Slightly effective 3-Somewhat effective

4-Very effective 5-Extremely effective

or

☐ N/A ☐ Do not know

Section III.18: *Contributing to improved environmental conditions for Canadians:*

3.22. To what extent do you think the R&D projects carried out through the IRC in SCMD are effective in terms of contributing to improved environmental conditions for Canadians as a result of improved organizational practices, strategies, and management systems (i.e., efficient use of energy, water and other resources, etc.)?

1-Not effective at all 2-Slightly effective 3-Somewhat effective
4-Very effective 5-Extremely effective
or
☐ N/A ☐ Do not know

Thank you for completing the survey.

APPENDIX C: RESULTS OF STATISTICAL ANALYSIS OF THE PILOT STUDY'S EVALUATION RESULTS FOR THE UNIVERSITY'S ROLE WITHIN THE NSERC IRC

C.1. Correlation between inputs criteria with each other

Input criterion	Input criterion	Correlation Coefficient	Interpretation
Qualified research team involved in R&D projects	---------	------------	---------------
Laboratories and facilities involved in R&D projects	Trust in industrial partners working on R&D projects	0.785 (p =0.007)	Strong positive
Industry connections facilitated by R&D collaborations	Funding	0.727 (p =0.017)	Strong positive
Industry connections facilitated by R&D collaborations	Teamwork effectiveness in R&D collaborations	0.572 (p =0.084)	Moderate positive
Funding	Teamwork effectiveness in R&D collaborations	0.905 (p =0.000)	Strong positive
Trust in industrial partners working on R&D projects	---------	------------	---------------
Time spent on R&D projects	---------	------------	---------------
Previous R&D achievements	---------	------------	---------------
Teamwork effectiveness in R&D collaborations	---------	------------	---------------

C.2. Correlation between inputs and outputs criteria

Input criterion	Output criterion	Correlation coefficient	Interpretation
Qualified research team involved in R&D projects	Publishing papers, technical reports, newsletters, books, and manuals/guides	0.848 (p =0.002)	Strong positive
Qualified research team involved in R&D projects	Participating in advisory committee meetings of the IRC in SCMD	0.617 (p =0.057)	Moderate positive
Laboratories and facilities involved in R&D projects	Publishing papers, technical reports, newsletters, books, and manuals/guides	0.557 (p =0.094)	Moderate positive
Laboratories and facilities involved in R&D projects	Participating in advisory committee meetings of the IRC in SCMD	0.648 (p =0.043)	Moderate positive
Industry connections facilitated by R&D collaborations	-------------	---------------	----------------
Funding	Introducing presentations and posters at conferences and seminars	0.642 (p =0.045)	Moderate positive
Trust in industrial partners working on R&D projects	Publishing papers, technical reports, newsletters, books, and manuals/guides	0.592 (p =0.071)	Moderate positive
Time spent on R&D projects	---------	------------	---------------
Previous R&D achievements	Communicating R&D progress and results through the university research team's website	-0.557 (p =0.094)	Moderate negative
Teamwork effectiveness in R&D collaborations	Training industry professionals to enhance their performance and knowledge	0.579 (p =0.079)	Moderate positive
Teamwork effectiveness in R&D collaborations	Introducing presentations and posters at conferences and seminars	0.639 (p =0.047)	Moderate positive

C.3. Correlation between outputs criteria with each other

Output criterion	Output criterion	Correlation coefficient	Interpretation
Doing research in collaborative R&D teams	Publishing papers, technical reports, newsletters, books, and manuals/guides	0.598 (p =0.068)	Moderate positive
Developing tools and solutions to problems through R&D projects	Participating in advisory committee meetings of the IRC in SCMD	-0.596 (p =0.069)	Moderate negative
Training industry professionals to enhance their performance and knowledge	Organizing workshops to present the results of R&D projects	0.660 (p =0.038)	Moderate positive
Publishing papers, technical reports, newsletters, books, and manuals/guides	-------	-------	---------------------
Introducing presentations and posters at conferences and seminars	-------	--------	--------------------
Communicating R&D progress and results through the university research team's website	Participating in advisory committee meetings of the IRC in SCMD	0.591 (p =0.072)	Moderate positive
Organizing workshops to present the results of R&D projects	Participating in advisory committee meetings of the IRC in SCMD	-0.616 (p =0.058)	Moderate negative
Participating in advisory committee meetings of the IRC in SCMD	------------	------------	----------------

C.4. Correlation between outputs and short-term outcomes criteria

Output criterion	Short-term outcome criterion	Correlation coefficient	Interpretation
Doing research in collaborative R&D teams	Linking scientific theories with practical applications	0.809 (p =0.005)	Strong positive
Doing research in collaborative R&D teams	Increased university research capacity in an area directly related or complementary to the IRC	0.696 (p =0.025)	Moderate positive
Developing tools and solutions to problems through R&D projects	Increasing the knowledge of researchers	-0.763 (p =0.010)	Strong negative
Developing tools and solutions to problems through R&D projects	Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program”	0.757 (p =0.011)	Strong positive
Training industry professionals to enhance their performance and knowledge	Linking scientific theories with practical applications	0.630 (p =0.051)	Moderate positive
Training industry professionals to enhance their performance and knowledge	Increased university research capacity in an area directly related or complementary to the IRC	0.576 (p =0.081)	Moderate positive
Training industry professionals to enhance their performance and knowledge	Enhanced networks/partnerships (universities and industrial partners)	-0.769 (p =0.009)	Strong negative
Publishing papers, technical reports, newsletters, books, and manuals/guides	Graduating highly experienced personnel	0.577 (p =0.081)	Moderate positive
Publishing papers, technical reports, newsletters, books, and manuals/guides	Linking scientific theories with practical applications	0.656 (p =0.040)	Moderate positive
Publishing papers, technical reports, newsletters, books, and manuals/guides	Increased university research capacity in an area directly related or complementary to the IRC	0.613 (p =0.060)	Moderate positive
Publishing papers, technical reports, newsletters, books, and manuals/guides	Improving the reputation of researchers among their peers	0.684 (p =0.029)	Moderate positive
Introducing presentations and posters at conferences and seminars	Linking scientific theories with practical applications	0.595 (p =0.069)	Moderate positive
Introducing presentations and posters at conferences and seminars	Increased university research capacity in an area directly related or complementary to the IRC	0.613 (p =0.060)	Moderate positive
Communicating R&D progress and results through the university research team’s website	Better development in the research facilities	-0.745 (p =0.013)	Strong negative
Organizing workshops to present the results of R&D projects	Linking scientific theories with practical applications	0.610 (p =0.061)	Moderate positive

Output criterion	Short-term outcome criterion	Correlation coefficient	Interpretation
Organizing workshops to present the results of R&D projects	Increased university research capacity in an area directly related or complementary to the IRC	0.787 (p =0.007)	Strong positive
Organizing workshops to present the results of R&D projects	Enhanced networks/partnerships (universities and industrial partners)	-0.826 (p =0.003)	Strong negative
Organizing workshops to present the results of R&D projects	Better development in the research facilities	0.660 (p =0.038)	Moderate positive
Participating in advisory committee meetings of the IRC in SCMD	Increasing the knowledge of researchers	0.764 (p =0.010)	Strong positive
Participating in advisory committee meetings of the IRC in SCMD	Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	-0.607 (p =0.063)	Moderate negative
Participating in advisory committee meetings of the IRC in SCMD	Improving the reputation of researchers among their peers	0.579 (p =0.079)	Moderate positive

C.5. Correlation between short-term outcomes criteria with each other

Short-term outcome criterion	Short-term outcome criterion	Correlation coefficient	Interpretation
Graduating highly experienced personnel	---------	-------------	--------------
Better understanding of industry needs	---------	-------------	--------------
Linking scientific theories with practical applications	Increased university research capacity in an area directly related or complementary to the IRC	0.861 (*p* =0.001)	Strong positive
Linking scientific theories with practical applications	Enhanced networks/partnerships (universities and industrial partners)	-0.758 (*p* =0.011)	Strong negative
Increased university research capacity in an area directly related or complementary to the IRC	Enhanced networks/partnerships (universities and industrial partners)	-0.705 (*p* =0.023)	Strong negative
Increased university research capacity in an area directly related or complementary to the IRC	Better development in the research facilities	0.559 (*p* =0.093)	Moderate positive
Increasing the knowledge of researchers	Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	-0.758 (*p* =0.011)	Strong negative
Increasing the knowledge of researchers	Improving the reputation of researchers among their peers	0.787 (*p* =0.007)	Strong positive
Fostering improved collaboration and stable relationships with industry	Improved research quality of the university research team	0.690 (*p* =0.027)	Moderate positive
Enhanced networks/partnerships (universities and industrial partners)	Better development in the research facilities	-0.709 (*p* =0.022)	Strong negative
Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	---------	-------------	--------------
Improving the reputation of researchers among their peers	---------	-------------	--------------
Improved research quality of the university research team	---------	-------------	--------------
Improved industrial relevance of research	---------	-------------	--------------
Better development in the research facilities	---------	-------------	--------------

C.6. Correlation between short-term outcomes and medium-term outcomes criteria

Short-term outcome criterion	**Medium-term outcome criterion**	**Correlation coefficient**	**Interpretation**
Graduating highly experienced personnel	---------	--------------	---------------
Better understanding of industry needs	---------	-------------	---------------
Linking scientific theories with practical applications	---------	-------------	---------------
Increased university research capacity in an area directly related or complementary to the IRC	---------	-------------	---------------
Increasing the knowledge of researchers	Creation of innovative technologies	-0.761(p =0.011)	Strong negative
Fostering improved collaboration and stable relationships with industry	---------	-------------	---------------
Enhanced networks/partnerships (universities and industrial partners)	Satisfying industry needs	-0.705 (p =0.023)	Strong negative
Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	Creation of innovative technologies	0.561 (p =0.092)	Moderate positive
Improving the reputation of researchers among their peers	---------	--------------	-------------------
Improved research quality of the university research team	Satisfying industry needs	-0.559 (p =0.093)	Moderate negative
Improved research quality of the university research team	Creation of innovative technologies	-0.643 (p =0.045)	Moderate negative
Improved industrial relevance of research	Enhanced academic reputation of the department and/or university	-0.591 (p =0.072)	Moderate negative
Better development in the research facilities	Satisfying industry needs	0.559 (p =0.093)	Moderate positive
Better development in the research facilities	Enhanced feedback mechanism for better communication and collaboration with industry	0.645 (p =0.044)	Moderate positive
Better development in the research facilities	Employment of highly qualified personnel (HQP)	0.789 (p =0.007)	Strong positive

C.7. Correlation between medium-term outcomes and long-term outcomes criteria

Medium-term outcome criterion	Long-term outcome criterion	Correlation coefficient	Interpretation
Satisfying industry needs	Contributing to improved economic and social conditions for Canadians	0.633 (p =0.050)	Moderate positive
Satisfying industry needs	Contributing to improved environmental conditions for Canadians	0.678 (p =0.031)	Moderate positive
Creation of innovative technologies	Development of nationally and internationally-recognized expertise in various research areas	-0.672 (p =0.033)	Moderate negative
Enhanced academic reputation of the department and/or university	----------------	--------------	-------------
Enhanced feedback mechanism for better communication and collaboration with industry	---------	--------------	-------------
Expansion of the research program	---------	--------------	-------------
Enhancement of the management system for R&D projects	---------	--------------	-------------
Employment of highly qualified personnel (HQP)	---------	--------------	-------------

C.8. Correlation between long-term outcomes criteria with each other

Long-term outcome criterion	Long-term outcome criterion	Correlation coefficient	Interpretation
Development of nationally and internationally-recognized expertise in various research areas	---------	-------------	-------------
Enhancing Canada's level of technological innovation on a global scale	Enhancing the global competitiveness of the Canadian economy	0.774 (p =0.009)	Strong positive
Enhancing the global competitiveness of the Canadian economy	Contributing to improved economic and social conditions for Canadians	0.686 (p =0.029)	Moderate positive
Enhancing the global competitiveness of the Canadian economy	Contributing to improved environmental conditions for Canadians	0.772 (p =0.009)	Strong positive
Contributing to improved economic and social conditions for Canadians	Contributing to improved environmental conditions for Canadians	0.941 (p =0.000)	Strong positive
Contributing to improved environmental conditions for Canadians	---------	-------------	-------------

C.9. Descriptive statistics for composite indices of the university inputs criteria

Input criterion	Metric	Mean (standard deviation) of the composite index for each criterion	Interpretation of composite index
Qualified research team involved in R&D projects	• Total years of research and industrial work experience of the researchers involved in R&D projects • Personal management • Research and analysis • Project and task management • Commitment to quality • Professional behavior • Continuous learning	0.54 (0.11)	Good
Laboratories and facilities involved in R&D projects	• Number of Laboratories and/or research spaces • Quality of Laboratories and/or research spaces	0.32 (0.21)	Fair
Industry connections facilitated by R&D collaborations	• Number of R&D industrial partners of the IRC	0.40 (0.14)	Fair
Funding	• Amount of funds in Canadian dollars provided by the different partners of the IRC • Level of satisfaction of remuneration • Level of satisfaction of in-kind contributions provided by the partners of the IRC	0.43 (0.13)	Good
Trust in industrial partners working on R&D projects	• Integrity • Competence • Dependability	0.61 (0.21)	Very good
Time spent on R&D partnership	• Number of hours spent monthly on R&D projects within the IRC	0.57 (0.26)	Good
Previous R&D achievements	• Number of R&D projects with industry participants of the IRC completed on time and on budget • Total number of R&D projects with industry participants of the IRC	0.43 (0.23)	Good
Teamwork effectiveness in R&D collaborations	• Perceived cohesion • Perceived communication • Perceived support	0.60 (0.17)	Good

C.10. Descriptive statistics for composite indices of the university outputs criteria

Output criterion	Metric	Mean (standard deviation) for each criterion	Interpretation of composite index
Doing research in collaborative R&D teams	• Frequency of carrying out R&D projects in collaboration with industrial partners of the IRC • Number of basic, applied, and basic and applied R&D projects carried out within the IRC • Level of satisfaction with the collaboration on R&D projects within the IRC • Time spent in years by graduate students (i.e., doctorate and master's students) to complete their degrees within the IRC • Number of graduate students posted at industrial partners' organization and/or job sites within the IRC	0.52 (0.14)	Good
Developing tools and solutions to problems through R&D collaborations	• Frequency of implementing tools and solutions developed through R&D projects by the industrial partners of the IRC • Number of software applications developed through R&D projects within the IRC • Level of quality of R&D projects results within the IRC	0.70 (0.23)	Very good
Training of industry professionals to enhance their performance and knowledge	• Frequency of providing training to industry professionals • Number of training workshops carried out by university for industry • Number of trained industry professionals • Level of satisfaction of the outcomes of the training provided	0.41 (0.19)	Good
Publishing papers, technical reports, newsletters, books, and manuals/guides	• Number of different publications introduced by the university research team for the IRC • Level of quality of the different publications	0.46 (0.13)	Good
Introducing presentations and posters at conferences and seminars	• Number of posters and research posters introduced at conferences and seminars • Level of quality of the presentations and research posters introduced by the university research team for the IRC	0.36 (0.17)	Fair
Communicating R&D progress and results through the university research team's website	• Frequency of updating information on the IRC website regarding the progress of R&D projects • Level of quality of the website content regarding the R&D projects	0.53 (0.08)	Good
Organizing workshops to present the results of R&D projects	• Number of organized workshops by the university research team for the IRC to present outcomes and results of R&D projects • Level of quality of the organized workshops by the university research team for the IRC	0.22 (0.21)	Fair
Participating in advisory committee meetings of the IRC	• Number of management and technical advisory committee meetings in which the IRC chairholder participate in	0.67 (0.26)	Very good

C.11. Descriptive statistics for composite indices of the university outcomes criteria

Class of outcomes	Outcome criterion	Metric	Mean (standard deviation) for each criterion	Interpretation of composite index
Short-term Outcomes	Graduating highly experienced students	• Level of increase in the experience of the university research team by participating in R&D projects within the IRC	0.55 (0.28)	Good
	Better understanding of industry needs	• Level of improvement in the awareness of industry needs after participating in R&D projects within the IRC	0.55 (0.37)	Good
	Linking scientific theories with practical applications	• Level of alignment of R&D projects within the IRC with practical industry needs	0.55 (0.28)	Good
	Increased university research capacity in an area directly related or complementary to the IRC	• Level of increase in the university's research capacity since the start of the IRC	0.20 (0.42)	Poor
	Increasing the knowledge of researchers	• Level of increase in the knowledge and skills of the university research team by participating in R&D projects within the IRC	0.40 (0.52)	Fair
	Fostering improved collaboration and stable relationships with industry	• Level of improvement in collaboration between university and industry by working together on R&D projects within the IRC	0.55 (0.28)	Good
	Enhanced networks/partnerships (universities and industrial partners)	• Level of enhancement in the collaboration and interaction between the IRC chairholder and other industrial partners outside the IRC • Number of existing industrial partners who extend and discontinue their participation in the IRC at each renewal • Number of new industrial partners who join the IRC at each renewal • Number of industrial partners outside the IRC in which the university research team collaborate with based on successful R&D projects within the IRC	0.57 (0.11)	Good
	Enhanced collaborations and interaction between the chairholder and other colleagues in connection with the IRC program	• Level of enhancement in collaboration and interaction between the IRC chairholder other colleagues in connection with the IRC program	0.54 (0.26)	Good

Class of outcomes	Outcome criterion	Metric	Mean (standard deviation) for each criterion	Interpretation of composite index
Medium-term Outcomes	Improving the reputation of researchers among their peers	• Level of enhancement in the reputation of the university research team by participating in R&D projects within the IRC • Number of awards won regionally, nationally, and internationally by the university research team members by participating in R&D projects within the IRC	0.25 (0.28)	Fair
	Improved research quality of the university research team	• Level of improvement in the research conducted by the university research team since the start of the IRC	0.60 (0.39)	Good
	Improved industrial relevance of research	• Level of improvement in the industrial relevance of research conducted by the university research team since the start of the IRC	0.90 (0.32)	Excellent
	Better development in the research facilities	• The increase in the amount of funds in Canadian dollars invested in research facilities since the start of the IRC	0.50 (0.24)	Good
	Satisfying industry's needs	• Level of satisfaction of industry needs by the results of R&D projects carried out through the IRC	0.80 (0.24)	Very good
	Creation of innovative technologies	• Number of patentable, licensable, and innovative products developed through R&D projects within the IRC • Number of transferred products to industrial partners within the IRC • Number of innovative processes developed through R&D projects within the IRC	0.47 (0.15)	Good
	Enhanced academic reputation of the department and/or university	• Level of enhancement in the reputation of the department and/or university by participating in R&D projects with the industrial partners of the IRC • Number of new graduate student enrolled in the university research team for the IRC	0.62 (0.14)	Very good
	Enhanced feedback mechanism for better communication and collaboration with industry	• Level of enhancement in the feedback mechanism with industry after working together on different R&D projects within the IRC	0.65 (0.34)	Very good
	Expansion of the research program	• Level of increase in the research themes explored by the university research team by working with industrial partners of the IRC	0.30 (0.48)	Fair

Class of outcomes	Outcome criterion	Metric	Mean (standard deviation) for each criterion	Interpretation of composite index
	Enhancement of the management system for R&D projects	• Level of enhancement of R&D projects' management system by working with industrial partners of the IRC on R&D projects	0.80 (0.42)	Very good
	Employment of highly qualified personnel (HQP) (i.e., Undergraduate Students, Masters Students, Doctoral Students, Postdoctoral Fellows, Research Associates, Technical Writers, and Programmers)	• Number of trained university research team members within the IRC • Number of hired HQP from the university research team by the industrial partners of the IRC • Number of hired HQP from the university research team by other universities	0.33 (0.25)	Fair
Long-term outcomes	Development of nationally and internationally-recognized expertise in various research areas	• Level of influence of the different research themes in the construction domain nationally and internationally	0.30 (0.35)	Fair
	Enhancing Canada's level of technological innovation on a global scale	• Level of effect of the different research themes explored by the IRC on enhancing Canada's level of technological innovation	0.47 (0.28)	Good
	Enhancing the global competitiveness of the Canadian economy	• Level of effect of the different research themes explored by the IRC on enhancing the global competitiveness of the Canadian economy	0.50 (0.33)	Good
	Contributing to improved economic and social conditions for Canadians	• Level of effect of the different research themes explored by the IRC on improving the economic and social conditions for Canadians	0.40 (0.34)	Fair
	Contributing to improved environmental conditions for Canadians	• Level of effect of the different research themes explored by the IRC on improving the environmental conditions for Canadians	0.50 (0.29)	Good