

STATE OF BRIDGE MANAGEMENT IN CANADA

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ABSTRACT

Bridges are key elements of all horizontal transportation networks. The primary objective of this paper is to investigate and document bridge-management practices in Canada at the federal, provincial/territorial, and municipal levels.

The research methods used include a literature review, data collection (surveys), data analysis, and conclusions. The survey was sent to all provincial/territorial and federal jurisdictions. Nine of ten provincial, three of three territorial, and two of nine federal agencies responded to the survey.

Currently, only four provinces have computerized Bridge Management Systems (BMS). The Ontario Structure Inspection Manual (OSIM), developed by province of Ontario, is the most widely used bridge inspection system in Canada. At present, five provinces employ this system to conduct bridge inspections.

This paper identified six important municipal bridge-management challenges. It is recommended that higher tier of government, i.e., federal and provincial, should play a larger role to support municipalities with bridge management.

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LIST OF ABBREVIATIONS

| | |
|-------------|--|
| AMB | Area Bridge Manager |
| AMO..... | Association of Municipalities of Ontario |
| ACR..... | Atmospheric Corrosion Resistant |
| BCI..... | Bridge Condition Index |
| BEADS..... | Bridge Expert Analysis and Decision Support |
| BIM..... | Bridge Inspection and Maintenance |
| BMIS..... | Bridge Management Information System |
| BMS..... | Bridge Management System |
| BSI..... | Bridge Sufficiency Index |
| MoT..... | British Columbia Ministry of Transportation and Infrastructure |
| BCF-CC..... | Building Canada Fund-Communities Component |
| COMRIF..... | Canada-Ontario Municipal Rural Infrastructure Fund |
| EOWC..... | Eastern Ontario Warden’s Caucus |
| FHWA..... | Federal Highway Administration |
| OIPC..... | Infrastructure Projects Corporation |
| ISF..... | Infrastructure Stimulus Fund |
| MII | Inventory inspection module |
| LCC..... | Life Cycle Cost |
| LSR..... | Local Services Realignment |
| MR&R..... | Maintenance, Rehabilitation, and Repair |
| MIT..... | Manitoba Infrastructure and Transportation |
| MTO..... | Ministry of Transportation of Ontario |

MTQ.....Ministry of Transports of Quebec

MDW..... Municipal Data Works

MIII..... Municipal Infrastructure Investment Initiative

NBIS..... National Bridge Inspection Standards

NBI.....National Bridge Inventory

NESS.....Network Expansion Support System

NBDOT..... New Brunswick Department of Transportation

TIR..... Nova Scotia Transportation & Infrastructure Renewal

OBMS..... Ontario Bridge Management System

OGRA..... Ontario Good Roads Association

OSIM.....Ontario Structure Inspection Manual

OSRMOntario Structure Rehabilitation Manual

PVS..... Project Value System

PTH.....Provincial Trunk Highways

PTHIA.....Public Transportation and Highway Improvement Act

RFP.....Request for Proposal

RCCAO..... Residential and Civil Construction Alliance of Ontario

RoMaRa..... Roadway Maintenance and Rehabilitation Application

RIII.....Rural Infrastructure Investment Initiative

MPS..... Strategic Planning Module

SHM..... Structural Health Monitoring

GSQ..... Système de Gestion des Structures

TIMS..... Transportation Infrastructure Management System

TRB.....Transportation Research Board

CHAPTER 1. INTRODUCTION

1.1. Background

A bridge has traditionally been defined as a structure that provides a crossing over an obstruction or gap. Most bridges provide this function over essentially two groups of obstructions: those over water and those over land obstructions [1]. Bridges are key elements of any transportation network because of their strategic location and the dangerous consequences when they fail or when their capacity is impaired [2].

An effective bridge-management program is a prerequisite to a successful horizontal transportation system. A good bridge-management program would serve the mission of any government agency, i.e., a safe, economical, and effective transportation network to allow the movement of people and goods on land.

The importance of and need for an effective bridge-management program cannot be overstated, especially in light of the aging infrastructure and recent collapse of bridges in North America and Canada. High traffic volumes, heavy trucks, salt exposure, and freeze/thaw cycles, all reduce the lifespan of a bridge.

This paper will focus on the management practices of vehicular bridges in Canada under the jurisdiction of federal, provincial/territorial (only ministry of transportation), and municipal governments. Table 1 shows the bridge inventory for the three levels of government. Bridges managed by railway companies, private companies, First Nation groups, and other provincial government ministries and agencies (e.g., the ministry of Natural Resources, etc.) are not discussed in this paper. Throughout the document in all of the tables provinces are arranged from Pacific Ocean to Atlantic Ocean followed by the Territories in a similar fashion.

Table 1: Inventory of Bridges in Canada

| Province/Territory | Federal Bridges [3] | Provincial/Territorial Bridges | Municipal Bridges | Total Bridges |
|-------------------------|---------------------|--------------------------------|-------------------|---------------|
| British Columbia | 76 | 2,700 | 17,300 [4] | 20,076 |
| Alberta | 104 | 4,000 | 9,800 | 13,904 |
| Saskatchewan | 33 | 792 | 2,800 | 3,625 |
| Manitoba | 8 | 2,200 | N.A. | 2,208 |
| Ontario | 55 | 2,721 | 13,000 | 15,776 |
| Quebec | 69 | 8,883 | N.A. | 8,952 |
| New Brunswick | 19 | 3,290 | 98 | 3,407 |
| Prince Edward Island | 1 | 1,189 | 0 | 1,190 |
| Nova Scotia | 23 | 4,100 | N.A. | 4,123 |
| Newfoundland & Labrador | 31 | 818 [3] | N.A. | 849 |
| Yukon Territory | N.A. | 129 [3] | 5 | 134 |
| Northwest Territories | N.A. | 70 [3] | N.A. | 70 |
| Nunavut Territory | N.A. | 2 | N.A. | 2 |
| Total | 419 | 30,894 | 43,003 | 74,316 |

1.2. Aging Infrastructure

As the third millennium dawns, Canada and the United States are in the midst of a “bridge crisis,” especially after the latest collapse of a bridge in Laval City, Quebec, and Minneapolis, Minnesota [4]. With the aging of its infrastructure, Canada, like other developed countries, is facing a critical problem to deal with the complex and fragmental issues existing in

current bridge infrastructure management [4]. Much of the infrastructure in North America was built in the post World War II era and are nearing the end of their useful life. There is an urgent need for governments to update, repair, rehabilitate, or replace aging infrastructure [4].

Depending on the type of bridge, construction methodology, and degree of maintenance, it is expected that most bridges will require costly rehabilitation or replacement after 50 years of service life. Bridges built prior to the 1970s did not use air-entrained concrete and coated (epoxy) steel reinforcing bars to protect from the effects of freeze-thaw cycles and the application of winter salt. Accordingly, bridge decks, railings, and barrier walls are all likely candidates for expensive replacement on the majority of these older bridges. Other concrete and steel structural components exposed to traffic and chlorides, such as substructure (e.g., piers and caps) and superstructure (e.g., girders and stringers) elements, are also likely to require rehabilitation [4].

Table 2 clearly demonstrates the looming problem. The majority of provincial bridges are between or over 26-50 years old. Nova Scotia has the most (50%) bridges over 51 years old, followed by Federal Bridge Corporation Limited (43%), Quebec (31.2%), Yukon Territory (25%), Ontario and Saskatchewan (19%), New Brunswick and Manitoba (18%), Prince Edward Island (16%), British Columbia (13%), Blue Water Bridge Canada (1%), and Northwest Territories (0.01). Based on the above the importance of effective bridge management, practices and systems cannot be over emphasized.

1.3. Problem Statement

Bridges are very important elements of horizontal transportation systems. Due care must be given to them because bridges are aging and because a bridge failure/collapse could result in considerable loss of life, property, environment, and economy.

Table 2: Age of Bridges

| Government | Type of Government | No. of Bridges | Age of Bridges | | | | | | |
|------------------------------------|--------------------|----------------|--------------------|---------------------|---------------------|----------------------|---------------------|--------------------|--------------------|
| | | | < 25 Years Old (%) | 25-50 Years Old (%) | 51-75 Years Old (%) | 76-100 Years Old (%) | > 100 Years Old (%) | > 51 Years Old (%) | Average Age (Year) |
| British Columbia | Province | 2,700 | 39 | 48 | 12 | 0.5 | 0.5 | 13 | 26-50 |
| Alberta | Province | 4,000 | N.A | N.A | N.A | N.A | N.A | N.A | 51-75 |
| Saskatchewan | Province | 3,000 | 23 | 60 | 18 | 1 | N.A | 19 | 26-50 |
| Manitoba | Province | 2,200 | 14.3 | 67.8 | 15.9 | 2.1 | 0 | 18 | 26-50 |
| Ontario | Province | 2,721 | 22.7 | 56.7 | 17.8 | 1.1 | 0.1 | 19 | 26-50 |
| Quebec | Province | 8,883 | 20.7 | 48.1 | 25.5 | 4.8 | 0.9 | 31.2 | 26-50 |
| New Brunswick | Province | 3,487 | 41 | 41 | 12 | 5 | 1 | 18 | 26-50 |
| Prince Edward Islands | Province | 1,189 | 24 | 40 | 13 | 3 | 0 | 16 | 26-50 |
| Nova Scotia | Province | 4,100 | 20 | 30 | 40 | 5 | 5 | 50 | 26-50 |
| Newfoundland & Labrador | Province | N.A | N.A | N.A | N.A | N.A | N.A | N.A | N.A |
| Yukon Territory | Territory | 128 | 38 | 37 | 25 | 0 | 0 | 25 | 26-50 |
| Northwest Territories | Territory | 80 | 77 | 22.99 | 0.01 | - | - | 0.01 | |
| Nunavut Territory | Territory | 2 | N.A | N.A | N.A | N.A | N.A | N.A. | N.A |
| Federal Bridge Corporation Limited | Federal | 7 | - | 57 | 43 | - | - | 43 | 51-75 |
| Blue Water Bridge Canada | Federal | 2 | 1 | - | 1 | - | - | 1 | < 25 |

For bridge owners to develop effective bridge management strategies, it is important for them to have a thorough knowledge of the limitations of their current bridge-management practices and challenges. At present, there isn't enough information available that outline bridge-management practices or challenges faced by the bridge owners for the three administrative levels of government, i.e., federal, provincial/territorial, and municipal in Canada. Without the essential information strategies cannot be devised to effectively manage bridges. This research provides essential bridge inspection and maintenance practices of federal and provincial/territorial ministries of transportation and challenges faced by Canadian municipalities while managing their bridges, so that strategies can be devised to manage bridges effectively and improvement can be made.

1.4. Research Objectives

The main goal of this paper is to identify and catalogue information about current state of bridge-management in Canada, which will facilitate the development of better strategies for effective management of bridges at three administrative levels of government. To achieve this goal, the research is broken into two objectives as follows:

- (a) To obtain and document bridge inspection and maintenance practices of federal and provincial/territorial ministries of transportation.
- (b) To document challenges currently faced by Canadian municipalities while managing their bridges.

1.5. Research Contributions

The research study investigates and documents bridge inspection and maintenance practices at the federal and provincial/territorial levels and bridge management i.e., inspection and maintenance challenges at the municipal level. The research study aims to provide an

integrated database of bridge inspection and maintenance practices of provincial/territorial ministries of transportation and a list of key bridge-management challenges faced by Canadian municipalities.

Responses from the provincial/territorial transportation ministries about their bridge inspection and maintenance practices are summarized in 11 tables in Chapter 5:

Provincial/Territorial Bridges, which forms a database of their bridge inspection and maintenance practices. The six important municipal bridge-management challenges determined by this paper are listed in Table 4 in Chapter 2. Literature Review.

1.6. Research Methodology

The methodology for achieving the objectives of the paper is described in detail in Chapter 3. The following sections are brief descriptions of each step.

1.6.1. Provincial/Federal Bridge Management

- Literature review - A review of the literature and related recent surveys on the subject were studied to form the conceptual design.
- Survey questionnaire design - After the literature review survey questionnaire was formulated, the questionnaire was divided into seven topics/sections namely structure of the organization, bridge-inspection data, personnel qualifications, process control, type of equipment used, documentation, and respondents' observation of bridge management in Canada. A combination of 52 closed- and open-ended questions was included on this survey.
- Structured survey questionnaire - This study sent structured questionnaires to all provincial, territorial, and federal transportation ministries responsible for bridge

management in Canada. Nine of ten provincial, three of three territorial, and two of nine federal agencies responded to the survey.

- Documentation - Feedback from the provincial/territorial transportation ministries is obtained and documented in 17 tables in Chapter 5. Provincial/Territorial Bridges.

1.6.2. Municipal Bridge Management

- Literature review – Through literature review, municipal bridge management challenges were first understood.
- Identification of various challenges faced by municipalities – Through literature review, municipal bridge management challenges were first identified and then crosschecked with the responses of provincial agencies to the standard survey questionnaire. Challenges were lumped into 4 categories namely oversight, regulation, outreach, and miscellaneous. Table 3 lists the municipal-bridge management challenges extracted from the previous studies.
- Identification of top 6 challenges - challenges were refined based upon importance, severity, and relevance. Some of the similar challenges were merged together. The possible total number of challenges added up at six. Table 4 lists the possible municipal bridge-management challenges identified by this study.

1.7. Paper Organization

This paper is divided into six chapters following the Introduction and Abstract, which describes the research methodology adopted:

- Chapter 2. Literature Review: This chapter first identifies information sources, i.e., literature from published reports and documents. Then, the chapter presents the definition and components of bridge management systems (BMS).
- Chapter 3. Research Methodology: This chapter illustrates methods used in this research, such as planning and formulating the structured questionnaire.
- Chapter 4. Bridge Management by Level of Government: This chapter identifies different levels of bridge management in Canada. There are primary three different administrative levels for the management of vehicular bridges in Canada: federal (national), provincial/territorial, and municipal (local). This chapter explores the bridge management of federal agencies. This chapter documents the bridge-management practices of Canadian provincial and territorial transportation ministries. Information has been collected based on the literature review, survey questionnaire, and direct communication (telephone calls and emails) with agencies and engineers related to bridge management.
- Chapter 5. Municipal Bridges: This chapter explores some of the challenges that municipal bridge owners are facing when managing their bridges. Through the literature review, municipal bridge management challenges were first identified and then crosschecked with the responses of provincial agencies to the standard survey questionnaire.
- Chapter 6. Conclusions: This chapter summarizes the research paper and suggests recommendations that should be adopted to improve bridge-management practices, with a particular focus on municipal bridges.

CHAPTER 2. LITERATURE REVIEW

2.1. Review of Previous Studies: Municipal Bridge Management

This paper provides a number of challenges faced by municipalities. Through the literature review, municipal bridge management challenges were first identified and then crosschecked with the responses of provincial agencies to the standard survey questionnaire. The following paragraphs outline the studies, reports, and papers conducted and published by a number of authors and organizations about bridge management challenges faced by municipalities.

The Marshall, Macklin, Monaghan (MMM) Group conducted a study to broadly and objectively review the current state of Ontario's bridge infrastructure. The report stated that municipalities are the largest and most important bridge infrastructure owners in the province of Ontario. The study did not offer a comparison or statistical analysis for the bridges in Ontario because there is no comprehensive bridge inventory of municipally owned bridges in the province. The study does, however, provide a number of recommendations to promote public safety and the sustainability of Ontario's bridge infrastructure. For this report, the MMM Group prepared a questionnaire and distributed it to the representatives of over 440 Ontario municipalities. The questionnaires that were mailed out, information was received or made available from 150 municipalities (approximately 1 of 3), including information from 89 municipalities associated with the Eastern Ontario Warden's Caucus (EOWC). The data collected encompassed approximately 4,000 of the 12,000 municipal bridges (1 of 3) and 2,800 of the 5,400 municipal culverts (1 of 2) [5].

Mirza, Saeed provided an analysis of the survey results and an estimate of the municipal infrastructure deficit. The survey indicated that municipalities need an additional \$21.7 billion to

maintain and upgrade the existing transportation infrastructure assets. The survey considered roads, sidewalks, bridges, and curbs as part of the transportation infrastructure category. This report was based on a survey of 85 municipalities, ranging in size from less than 10,000 to more than 1 million people, representing 46% of Canada's population [6].

The Ontario, Legislative Assembly, Standing Committee on Public Accounts audit of provincial bridges states that municipal bridges in Ontario are subject to the same high standards as provincial bridges and that there is no single body responsible for bridge oversight. For this report, the audit team surveyed about 130 Ontario municipalities, and almost 60% responded. The team sought information about what systems municipalities used to keep track of bridge inventories and to report on the inspections as well as how they perceived the current operating and funding arrangements. The team met with representatives from 10 large municipalities to discuss their survey responses; the team also met with representatives from the Association of Municipalities of Ontario (AMO) and the Ontario Good Roads Association (OGRA) [7].

The Transportation Association of Canada's (TAC) municipal subcommittee of strategic planning committee identifies 11 key municipal transportation challenges common to all municipalities. TAC is a Canadian national center of transportation expertise and a not-for-profit association. In June of 1998, TAC's Strategic Planning Committee established a Municipal Subcommittee to identify the major challenges/issues facing municipalities with respect to transportation as well as the role that TAC can play in assisting municipalities with meeting the challenges and resolving the issues. The subcommittee's initial discussion paper was issued in draft form to TAC's 150+ municipal members as well as to all other Canadian municipalities with populations of 25,000 or more [8]. The main issues and challenges included funding/financing, technology deployment, an affordable asset-management system, safety,

standards and guidelines, environmental considerations, public information, and education/training [9].

2.1.1. Identification of Possible Challenges: Municipal Bridge Management

This study identified several bridge-management challenges faced by municipalities, based on the literature review of the previous research studies and the survey which was sent to provincial agencies. These challenges were refined based upon importance, severity, and relevance. Some of the similar challenges were merged together, and some new ones were added. The possible total number of challenges added up at six. Table 3 lists the municipal-bridge management challenges extracted from the previous studies while Table 4 lists the possible municipal bridge-management challenges identified by the present study.

2.2. Review of Previous Studies: Provincial/Federal Bridge Management

One of the objectives of this paper is to obtain and document bridge inspection and maintenance practices of federal and provincial/territorial ministries of transportation. For this purpose, the following studies were reviewed:

In 2007 the Transportation Research Board (TRB) studied the bridge inspection practices in the United States and selected foreign countries, including six provincial and municipal transportation agencies in Canada: the provincial agencies of Alberta, New Brunswick, Ontario, and Quebec as well as the municipal agencies of Edmonton and Ottawa. The synthesis is a collection of information about the formal inspection practices of departments of transportation (DOTs). These inspections are primarily visual, and they provide data for bridge registries and databases. For U.S. inspection practices, this synthesis reports on inspection personnel, inspection types, and inspection quality control and quality assurance.

Table 3: Municipal Bridge-Management Challenges Extracted from Previous Research Studies

| Category | Challenges | References | | | | |
|---------------|--|------------|-----|-----|-----|---|
| | | [5] | [6] | [7] | [8] | A |
| Oversight | No central database | x | x | x | | x |
| | No comprehensive bridge inventory | x | x | x | | x |
| | Lack of oversight from provinces | x | x | x | | x |
| Regulation | Roles and responsibilities not clearly defined | x | | x | | |
| | Lack of legislation concerning the safety of bridges | x | | x | | x |
| | Non-uniform guidelines and standards across municipalities within a province | | | x | x | x |
| | Variable or no municipal Bridge Management System | x | x | x | | x |
| | Downloading (Giving) of bridges from provinces to municipalities | x | x | x | | x |
| Outreach | Lack of expertise | x | x | | | x |
| | Lack of funds | x | x | x | | x |
| | Increased municipal infrastructure deficit | | x | | | |
| | Lack of ongoing technical and management training | | | | x | x |
| | Retention of employees | | | | x | |
| Miscellaneous | Deferred maintenance | | x | x | | |
| | New infrastructure needs | | x | | | |
| | Aging bridge inventory | x | x | x | | x |

References: A = Responses of provincial/territorial ministries of transportation to the standard survey questionnaire.

Table 4: Possible Municipal Bridge-Management Challenges Sorted in Alphabetical Order

| No. | Municipal Bridge-Management Challenges |
|-----|--|
| 1 | Downloading (giving away) bridges from provinces to municipalities |
| 2 | No central database and comprehensive bridge inventory |
| 3 | Lack of funds and expertise |
| 4 | Legislation for bridge inspection and management |
| 5 | Provincial oversight role |
| 6 | Variable or no Municipal Bridge Management System across provinces/territories |

Staff titles and functions in the inspection programs are reported, together with the qualifications and training of personnel, formation of inspection teams, and assignment of teams to bridges. Inspection types are described in terms of their scope, methods, and intervals. Quality-control and quality-assurance programs are reviewed in terms of the procedures employed, staff involved, quality measurements obtained, and the use of quality findings in DOT inspection programs. Foreign practices are presented in the same organization of inspection personnel, types, and quality programs. Comparisons of U.S. and foreign inspection practices are included [10].

In 2007, Hammad, Amin et al studied the current state of Bridge Management Systems (BMS) in Canada. In the paper, seven provinces' BMSs were studied: Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, Quebec, and Prince Edward Island. The paper discussed a new research project at Concordia University aimed at building a Canadian National Bridge Inventory (CNBI) similar to the NBI used in the United States [4].

2.3. Bridge Management System (BMS)

A BMS is a system designed to optimize the use of available resources for the inspection, maintenance, rehabilitation, and replacement of bridges [11]. A BMS facilitates a bridge manager in keeping him/her fully informed about the physical condition of the bridges under his/her control and making informed decisions about future maintenance, rehabilitation, or replacement activities. At the heart of the system is a database built upon the information obtained from the regular inspection and maintenance activities and containing a register of the bridges [12].

A BMS is more than a collection of facts; it is a system that looks at all of the information and data concerning bridges and is able to make comparisons in order to rank each one in order of its importance within the overall infrastructure with regards to safety and budgetary constraints. Basically, a BMS should be able to tell the bridge manager where he should be spending his funds in the most efficient way [12]. Thus, the major objective of a BMS is to assist a bridge manager in making optimal decisions regarding allocation of a budget to the maintenance, rehabilitation, and replacement (MR&R) needs of individual bridges (project level) or a group of bridges (network level) based on their life cycle cost (LCC) assessment [13]. A BMS has several components, namely, inventory component, inspection component, deficiencies component, financial component, and management component [12].

2.3.1. Inventory Component

This component stores all of the information about the bridge in terms of its name, location, and construction and also provides the starting point for the system. It requires reviewing drawings and maintenance records as well as a “walkover survey” to get familiar with the bridge (It also enables a check to be made onsite for the existing drawings from the drawing

register.) Record cards need to be established (or checked if they already exist), and finally, a computer-based database established to provide information for the management system [12].

2.3.2. Inspection Component

This component stores information from the inspection proformas and reports, which includes information about the general condition of the bridge, the specified treatment, the priority given to past remedial works, and the cost. This component helps the inspectors who are about to embark on an inspection and those responsible for budgetary control [12].

2.3.3. Deficiencies Component

If an inspection highlights a defect, then a process is put in motion to select the relevant data from the inspection report about the condition rating of the bridge member under inspection, the type of defect, its cause, the proposed remedy, and the possible cost. If the original inspector was unable to decide on the best course of remedial action, then the description of the problem together with the site sketches and/or digital photographs are examined with a view to specify the type, extent, and cost of the work required [12].

2.3.4. Financial Component

All eyes are on this module, especially in times of financial restraint. It processes all the cost information from past and present projects, and it should be able to produce regular and reliable financial reports [12].

2.3.5. Management Component

This component is considered to be the core of the system. This component analyzes all the information from the other modules, together with the costs and budgetary constraints, and attempts to prioritize maintenance and rehabilitation work required [12].

2.4. Bridge Management System Software

Pontis and Bridgit are the two widely used BMSs in the USA. The Ontario Bridge Management System (OBMS) is the most widely used BMS in Canada. The sections below describe each of the software.

2.4.1. Pontis

Pontis was developed by a coalition of Federal Highway Administration (FHWA), six DOTs, and the consulting joint venture of Optima Inc. and Cambridge Systematics [14]. Pontis was developed more than 10 years ago. It is licensed through the American Association of State Highway and Transportation Officials (AASHTO) to more than 45 U.S. state departments of transportation (DOTs) and other agencies nationally and internationally [15].

Pontis consists of five modules: a database module, a prediction module, a condition states and feasible action module, a cost module, and a network optimization module. The database module includes all the bridges in the network, and each bridge is divided into constituent elements. The deterioration module predicts future bridge conditions using the Markov approach. The cost module estimates repair and user costs [16].

2.4.1.1. Features

Pontis supports the entire bridge asset management cycle, allowing user input at every stage of the process. Pontis' advanced features include [15];

- Comprehensive inspection, preservation, project planning, and programming modules.
- Flexible bridge data presentations, including a user-configurable bridge desktop offering a common access point to all Pontis modules.
- Multimedia capability, supporting links to bridge as well as inspection photos and drawings.

- Extensive end-user customization capabilities, including reporting, data management, and helper applets, as well as functionality for changing labels and help tags for all user interface controls.
- Built-in support for the Microsoft SQL Server, Oracle and Sybase Adaptive Server Anywhere single or multi-user databases.
- BRIDGEWare integration, providing access to a common bridge database and the capabilities of the Virtis and Opis systems (licensed separately from AASHTO).
- Comprehensive online help, a user manual, a technical manual, and other support resources.

2.4.1.2. Drawbacks

- Pontis requires that it must be installed on every computer within the agency for use.
- Therefore, the task of installing Pontis is tedious. It is further complicated by the fact that Pontis creates updates, thus the new version of Pontis has to be installed onto all the computers. In addition, for every update, the data would have to be migrated into the new version [14].
- Pontis uses the incremental benefit/cost method to rank the recommended bridge projects. This method does not ensure that funds are put to the best possible use [16].

2.4.2. Bridgit

Bridgit was developed under an AASHTO-sponsored National Cooperative Highway Research Program (NCHRP). Bridgit is similar to Pontis in terms of its modeling and capabilities. For instance, it uses Markov theory to model the deterioration process. The primary difference is in the optimization model. Bridgit adopts the bottom-up approach to optimization. It can perform multi-year analysis and consider delaying actions on a particular bridge to a later date. Pontis only has this capability at the network level. This bottom-up approach provides

better results for smaller bridge populations than top-down programming. Its disadvantage is that the system is slower than Pontis for larger bridge populations. The main uses of Bridgit include scheduling and tracking MR&R activities, keeping history of MR&R, estimating the cost of MR&R, and creating and maintaining a list of MR&R actions [14].

2.4.3. Ontario Bridge Management System (OBMS)

Development of the OBMS began in 1998 and proceeded into the first steps of implementation in 2000. A set of project-level and network-level decision support models was subsequently completed in 2002 [17]. In the OBMS, there are three main models: deterioration, knowledge, and cost models [4].

Like other BMSs, OBMS also takes the Markovian deterioration model as a method of predicting the deterioration of bridges. Because the Markovian model is based on the assumption that future deterioration depends only on the current condition state, any other features of the bridge do not influence the prediction results [4].

Knowledge models are a unique feature of the OBMS and are used in several places in the analytical software. They are expressed as excel worksheet formulas and rely on Microsoft Excel behind the scenes to provide model parameters and to execute the formulas. The task of the knowledge model is to select a proper rehabilitation method when there are possibly one or more alternatives. The model uses decision trees and tables based on the ministry's *Structure Rehabilitation Manual* and *Structural Steel Coating Manual* [17].

In the cost model, the cost estimates for project alternatives are based on tender item unit costs. The MTO updates the unit costs according to actual contracts, continuously covering the different unit costs among the 12 districts in the province of Ontario. The MTO has a comprehensive cost database at the project level, called the Project Value System (PVS) that is

organized by tender item and is used for cost estimates. Each tender item object is responsible for examining the project scope for relevant treatments and determining the total quantity of the tender item required. The tender item object then consults PVS for a standard unit cost, and may modify that unit cost based on any known information about the bridge or the project. In the OBMS, there are approximately 50 treatment types [4].

CHAPTER 3. RESEARCH METHODOLOGY

3.1. Provincial/Federal Bridge Management

This research study sent structured questionnaires to all provincial, territorial, and federal transportation ministries responsible for bridge management in Canada. Responses to the standard questionnaire were obtained from nine provincial, three territorial, and two federal transportation agencies. Table 5 shows the detailed numbers of the survey questionnaire recipients and respondents.

Table 5: Number of Recipients and Respondents for the Research Survey

| Description | Provinces/Territories | Federal Agencies | Total |
|--------------------|-----------------------|------------------|------------|
| Questionnaire sent | 13 | 9 | 22 |
| Responses received | 12 (92.3%) | 2 (22.2%) | 14 (63.6%) |

The respondents were the provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edward Island, and Nova Scotia; Yukon Territory, Northwest Territories, and Nunavut Territory; as well as the Federal Bridge Corporation Limited and Blue Water Bridge Canada agencies. Feedback from the provincial/territorial transportation ministries is analyzed and summarized in 17 tables. The flow chart showing research methodology is demonstrated in Figure 1.

3.1.1. Questionnaire Design: Provincial/Federal Bridge Management

After the literature review survey questionnaire was formulated, the questionnaire was divided into seven topics/sections. The first section of the survey focused on the structure of the organization, i.e., provincial ministry of transportation. This section included administration and responsibilities for the bridge management.



Figure 1: Flow Chart Showing Research Methodology: Provincial/Federal Bridge Management

The second section targeted bridge-inspection data. This section included types and frequencies of inspections, requirements for special inspections (such as after a severe flood, earthquake, etc), type of BMS, the data items used for bridge management, the condition rating scale, etc. The third section included questions about personnel qualifications, such as bridge inspector's certifications, educational qualifications, physical qualifications, and training.

The fourth section consisted of process control. This section asked what role the provincial ministry played in the process of ensuring quality and safety for the bridges of other

jurisdictions, such as cities and municipalities. The fifth section included questions about the different equipment used for nondestructive evaluation, nondestructive testing, remote monitoring technologies, and other advanced testing equipment. The sixth section included questions on documentation, such as the types of standard inspection forms, report formats, and record keeping. The final section explored the respondents' observation of bridge management in Canada and asked the question about whether they would like to see federal regulation in Canada similar to the National Bridge Inspection Standards (NBIS) of the United States.

A review of the literature and related recent surveys on the subject were studied to form the conceptual design. The main concern regarding the survey study was the level of response from the provinces/territories and federal agencies because this research was an independent study and participation were voluntary. A combination of 52 closed- and open-ended questions was included on this survey.

The survey was sent to one person, typically the Bridge Management Engineer, who oversees bridge-management activities for the province/territory or federal agency. It took approximately 4 months for the survey to be completed, with a 92% response rate (12 provinces/territories). A sample of the questionnaire is attached in Appendix A.

The main purpose of the survey was to obtain and document provincial/territorial bridge inspection and maintenance practices. A synthesis of the findings is given in Chapter 5: Provincial/Territorial Bridges. As shown in Table 5 only two federal agencies responded to the survey, and these agencies only manage nine bridges. As a result, federal agencies' bridge-management practices were not documented.

3.2. Municipal Bridge Management

This paper does not offer a comparison or statistical analysis of the municipal bridges. The paper does, however, provide a number of challenges faced by municipalities and recommendations that will ensure a healthy future for municipal bridge infrastructure. Through the literature review, municipal bridge management was first identified and then crosschecked with the responses of provincial agencies to the standard survey questionnaire. Table 3 shows the identified municipal bridge-management challenges extracted from previous research studies, and Table 4 lists the six important municipal bridge-management challenges determined by this study. The flow chart showing research methodology is demonstrated in Figure 2.



Figure 2: Flow Chart Showing Research Methodology: Municipal Bridge Management

The identified municipal bridge-management challenges are discussed in detail in Chapter 6, along with a list of recommendations for improving municipal bridge management.

All the municipal bridge-management challenges are compiled into four groups: oversight, regulation, outreach, and miscellaneous. Table 6 lists the challenges according to their groups.

Table 6: Possible Municipal Bridge-Management Challenges According to Categories in Alphabetical Order

| Category | Challenges |
|---------------|--|
| Oversight | Lack of oversight from provinces |
| | No central database |
| | No comprehensive bridge inventory |
| Regulation | Downloading of bridges from provinces to municipalities |
| | Lack of legislation concerning the safety of bridges |
| | Non-uniform guidelines and standards across municipalities within a province |
| | Roles and responsibilities not clearly defined |
| | Variable or no municipal Bridge Management System |
| Outreach | Increased municipal infrastructure deficit |
| | Lack of expertise |
| | Lack of funds |
| | Lack of ongoing technical and management training |
| | Retention of employees |
| Miscellaneous | Aging bridge inventory |
| | Deferred maintenance |
| | New infrastructure needs |

CHAPTER 4: PROVINCIAL/TERRITORIAL BRIDGES

There are three primary different administrative levels for the management of vehicular bridges in Canada: federal (national), provincial/territorial, and municipal (local). There are some vehicular bridges that are under the management of private companies (e.g., forest resource companies, utility companies, mining companies, farmers, etc.); First Nation groups, especially in the north; and other provincial government ministries and agencies (e.g., the ministry of Natural Resources). This paper will not be discussing those bridges.

4.1. Federal Bridges

In the federal government, the departments responsible for bridge management are as follows: Transport Canada, Public Works and Government Services Canada, Parks Canada, and Indian and Northern Affairs Canada. Transport Canada's bridges are all managed by crown corporations or shared governance regimes, such as the National Capital Commission, Federal Bridge Corporation Limited, Blue Water Bridge Authority, Peace Bridge Authority, and the St. Lawrence Seaway Management Corporation. There are over 400 federal bridges (Table 1).

Public Works and Government Services Canada, which has most of the federal bridges, uses the *Bridge Inspection Manual* (BIM) for the inspection of its bridges. This manual is based on the *Ontario Structure Inspection Manual* (OSIM). Most federal bridges are inspected based on OSIM at regular intervals not exceeding two years.

There are 33 international bridges and tunnels between Canada and the United States (24 vehicular and 9 railway) [18]. On February 18, 2009, the International Bridges and Tunnels Regulations came into effect. The regulations stipulate the inspection requirements, frequency of inspection, qualification of the inspectors, reporting format, submission of the report, etc., by the owner to Transport Canada. Reports must be submitted every two years on maintenance and

operations (e.g., frequency and type of major maintenance performed, the inspection results, the types of vehicles permitted, and any restrictions applied to bridges and must also include any actions necessary to ensure the structures are kept in good condition. This regulation applies to international vehicular bridges and tunnels only [18].

4.2. Provincial/Territorial Bridges

The major findings from the survey are presented in this chapter. The 10 provincial and 3 territorial transportation agencies in charge of the majority of vehicular bridges in Canada are summarized in Table 7. Throughout this paper, the term “province/territory” or "provincial/territorial transportation agencies" refer to the agencies listed in Table 7.

4.3. Provincial/Territorial Bridge Management System (BMS)

The standard questionnaire which was sent to all 13 provincial and territorial governments asked whether they have computerized BMS, if yes date started using the system; type of BMS, is the system fully developed or under development, and in the absence of a computerized BMS, what system they are using.

As presented in Table 8, Saskatchewan, Manitoba, New Brunswick, Nova Scotia, Yukon Territory, and the Northwest Territories do not have a computerized BMS. Alberta has the oldest system while Prince Edward Islands has the newest system. Provinces/Territories which do not have a computerized BMS at present are utilizing combination of spreadsheets and inventory database to manage its bridges. The Ontario Bridge Management System (OBMS), developed by the province of Ontario, is the most widely used BMS.

Table 7: List of Provincial/Territorial Transportation Agencies Responsible for Bridge Management

| Province/Territory | Agency Responsible for Bridge Management |
|-------------------------|---|
| British Columbia | British Columbia Ministry of Transportation and Infrastructure |
| Alberta | Alberta Transportation |
| Saskatchewan | Saskatchewan Ministry of Highways and Infrastructure |
| Manitoba | Manitoba Infrastructure and Transportation |
| Ontario | Ministry of Transportation of Ontario (MTO) |
| Quebec | Transport Québec (MTQ) |
| New Brunswick | New Brunswick Department of Transportation |
| Prince Edward Island | Prince Edward Islands Department of Transportation and Infrastructure Renewal |
| Nova Scotia | Nova Scotia Transportation and Infrastructure Renewal |
| Newfoundland & Labrador | Department of Transportation |
| Yukon Territory | Highways and Public Works, Government of Yukon |
| Northwest Territories | Department of Transportation, Government of Northwest Territories |
| Nunavut Territory | Department of Community and Government Services, Government of Nunavut |

Table 8: Bridge Management System (BMS) of Provinces and Territories

| Province/Territory | Have Computerized BMS | Date Started Using Computerized BMS | Type Of BMS | Is the System Fully Developed or Under Development? | If No, Computerized BMS, What System Are You Using? |
|-----------------------|-----------------------|-------------------------------------|-------------|---|---|
| British Columbia | Yes | 1986 | BMIS | Continuous Development | - |
| Alberta | Yes | 1983 | BEADS | Under Development | - |
| Saskatchewan | No | | OBMS | Under Development | Database |
| Manitoba | No | - | - | In the process of selecting a BMS | Manually with the aid of spreadsheets and inventory database. |
| Ontario | Yes | 2000 | OBMS | Continuous Development | - |
| Quebec | Yes | 1987 | GSQ-6026 | Fully Developed | - |
| New Brunswick | No | 1995 | BRDG | Under Development | - |
| Prince Edward Islands | Yes | 2006 | OBMS | Under Development | - |
| Nova Scotia | No | - | - | Under Development | Each district currently maintains its own system of spreadsheets and has its own way of prioritizing its maintenance and rehabilitation projects. |
| Yukon Territory | No | 1990 | - | Not a full BMS | Database |
| Northwest Territories | No | - | - | - | Database |

4.3.1. British Columbia

British Columbia uses the Bridge Management Information System (BMIS) to manage its bridges. This system has been developed over the last 20 years. The last major upgrade of the system was in 2000. A map interface and a new module for inspection data entry and uploading from the field were added [4]. The following are some key strengths and weaknesses of the BMIS.

4.3.1.1. Strengths [4]

- Requirements were designed by those who use the system.
- Inspection forms are tailored to six different structure types: standard bridges, suspension/cable stayed bridges, culverts, tunnels, retaining walls, and sign structures.
- The system is integrated with the Ministry Road Inventory Management system.
- Geometry, material, and component type information are tailored to five different structure types.
- Provides inspections record percentage of each component in each condition state.
- Provides good training for inspectors.
- Has a map-based interface for recording inspection data on laptops and uploading to Oracle.
- Has access to drawing lists and electronic versions of drawings.
- Has the ability to store images and copies of documents and scanned reports.
- Provides a sufficiency ranking of structures.
- Has the ability to easily create custom reports using Oracle Discoverer.
- Provides various security levels.
- Can be accessed and used by private bridge-maintenance contractors.

4.3.1.2. Weaknesses [4]

- Does not have a module for budget forecasting and what-if scenarios.

4.3.2. Alberta

Among all the BMSs in Canada, the Bridge Expert Analysis and Decision Support system (BEADS) of Alberta has a different architecture than the other BMSs, such as Ontario BMS or Quebec BMS [4]. The system's primary objective is to facilitate consistent and accurate decisions to optimize the allocation of bridge funds; to evaluate system performance; and to plan and manage bridge construction, rehabilitation, and maintenance actions [19].

The BEADS system is a major component of a larger department-wide transportation management system named integrated Transportation Infrastructure Management System (TIMS), which consists of the Roadway Maintenance and Rehabilitation Application (RoMaRa), the Network Expansion Support System (NESS), and the Bridge Expert Analysis and Decision Support (BEADS) system. The BEADS system is an important component of TIMS. The purpose of TIMS is to justify and to rank the development, design, construction, rehabilitation, and maintenance needs of the highway system on a province-wide basis in order to optimize the allocation of funds to ensure long-term value [4].

The BEADS system provides a project-level (bottom-up) analysis that systematically identifies improvement needs related to condition and functionality with site-specific data. On the basis of the existing and predicted condition and functionality states, potential work activities are identified throughout the bridge structure's life cycle, including timing and the estimated cost of all actions. The work activities are grouped and assembled into feasible life-cycle strategies which are analyzed and ranked on an economic basis. The strategy with the lowest net present

value of costs is the recommended alternative and forms the starting point for further review by the department's bridge staff [19].

The BEADS system consists of individual modules to address the condition of elements and the functional limitations of bridge structures. Condition-related modules include the Superstructure and Paint Modules. Functionality-related modules include the Strength, Bridge Width, Bridge Rail, and Vertical Clearance Modules. The Strategy Builder Module assembles life-cycle strategies from the input received from each module. The Substructure and Replacement Modules provide supporting criteria and information to the Strategy Builder Module [19], which organizes life cycle strategies according to the received results from each of the above-mentioned modules [4].

Finally, an action plan table is created, including the year of replacement and all the information about possible work action plan, such as the number of work actions, duration of the action plan, year, cost, and description of each work action, as well as the net present value of the action-plan costs. The result will display the yearly functional needs, possible work actions to rectify functional needs, cost of possible work actions, and annual road user cost of not completing work actions [4].

4.3.3. Saskatchewan

The Saskatchewan Ministry of Highways and Infrastructure is in the process of selecting a BMS. At present, it manages its bridges with the aid of spreadsheets and an inventory database. Currently, the Ministry is in the process of developing its own simplified BMS. The system will be mainly inventory and only have minor analysis capability, i.e., no deterioration models. The proposed BMS would provide inspection schedules, a condition index, and a sufficiency index.

4.3.4. Manitoba

Manitoba Infrastructure and Transportation also is in the process of selecting a BMS. At present, it manages its bridges with the aid of spreadsheets and an inventory database [6]. The inspection results are currently stored in an Oracle database. This database is then queried for a prioritized structure of maintenance, rehabilitation, and repair (MR&R) actions [4].

4.3.5. Ontario

Development of the Ontario Bridge Management System (OBMS) began in 1998 and proceeded into the first steps of implementation in 2000. A set of project-level and network-level decision support models was subsequently completed in 2002 [17]. In the OBMS, there are three main models: the deterioration, knowledge, and cost models [4].

Like other BMSs, OBMS also takes the Markovian deterioration model as a method of predicting the deterioration of bridges[4]. The Markovian model takes advantage of the discrete condition states identified for inspections, to provide a simple way of describing the likelihood of each possible change in condition over time. Markovian models assume that measurements are taken or used at evenly-spaced intervals, and that the condition in the next interval is dependent only on the current condition state and not on any other attribute, including time. Markovian models require only two successive cycles of inspection, for most elements, before model estimation becomes possible.

Knowledge models are a unique feature of OBMS and are used in several places in the analytical software [17]. The task of the knowledge model is to select a proper rehabilitation method when there are one or more possible alternatives. The model uses decision trees and tables based on the ministry's *Structure Rehabilitation Manual* and *Structural Steel Coating Manual* [4].

In the cost model, the cost estimates for project alternatives are based on tender item unit costs. The MTO updates the unit costs according to actual contracts continuously covering the different unit costs among the 12 districts in the province of Ontario. The MTO has a comprehensive cost database at the project-level, called the Project Value System (PVS) that is organized by tender item and is used for cost estimates. Each tender item object is responsible for examining the project scope for relevant treatments and to determine the total quantity of the Tender Item required. The Tender Item object then consults PVS for a standard unit cost and may modify that unit cost based on any known information about the bridge or the project [4].

4.3.6. Quebec

The Ministry of Transport of Quebec (MTQ) started with a small BMS in 1987 and continuously improved it since then. From 1987 to 2008, the BMS was SGS-5016. In 2008, MTQ adopted a new system called *Système de Gestion des Structures* (GSQ-6026). The main features of the new system are as follows:

- It has a centralized database.
- There is an inventory inspection module (MII) at the user's station and on the laptop for inspection. It is the primary tool for entering, viewing, editing, and reporting structure and inspection information. It can store a set of photographs, a set of electronic documents, and mapping. It has the option of attaching photos of inspected components and archiving general inspections. It manages inspections; e.g., it can track upcoming inspection dates and frequency of inspections, etc. It identifies a list of work required on a structure and gives cost estimates [20].
- The Strategic Planning Module (MPS) of the new Quebec Bridge Management System developed for the Ministry of Transport of Québec (MTQ) includes a separate project-

level tactical planning dashboard that is the first of its kind in Canada and the first such tool developed for use in the French language [21].

- The MPS is a tool for simulating structural aging, identifying the most cost-effective work, and producing various investment scenarios and determining the consequences for the structures concerned. It helps with decision-making because it improves the identification of priorities and makes planning easier [21].
- The MPS features several analysis levels to fit traditional agency business processes: network-level budgeting and performance analysis, priority programming, automated project scoping, and treatment selection. The model framework handles preservation, functional improvements, and replacement; provides explicit control of the element and project alternatives to be considered; and has features to update deterioration models based on new inspection data [22].
- The MPS provides a family of decision-support tools to assist in bridge project planning and program planning as a part of the agency's overall asset management processes. All of the tools work within an integrated engineering-economic framework based on the concept of life cycle costs. The analyses are organized into three levels of detail. The levels are as follows [21]:
 - Element level, which focuses on a selected structural element of one bridge. This tool uses a Markovian deterioration model and a set of feasible treatments to produce multiple Element Alternatives, each of which is a possible corrective action to respond to deteriorated conditions. Functional improvements are also included at this level [21].

- Project level, which combines Element Alternatives into Project Alternatives, each of which represent a possible multi-year strategy to maintain service. The tool uses models of initial costs and life-cycle costs to evaluate the Project Alternatives [21].
- Network level, which combines the Project Alternatives on multiple bridges into Program Alternatives, each of which is a multi-year plan for work on all or part of a bridge inventory, designed to satisfy budget constraints and performance targets while minimizing life-cycle costs [21].

4.3.7. New Brunswick

At present, New Brunswick does not have a fully functional, computer-based application system to support bridge management. However, it has the following four major systems.

- BRDG (Custom Built) Bridge Information Management System, which stores inventory and inspection information.
- PDT (Custom Built) Program Development Tool, a tactical planning tool to develop capital programs up to 10 years in advance.
- LTIMP (www.Remsoft.com) Long-Term Investment Projection. This strategic planning and optimization software that lets the New Brunswick DOT forecast needs and establish the least life-cycle cost for the entire network across assets.
- OMS (www.hansen.com) Operations Management system, which records work done on bridge assets.

4.3.8. Prince Edward Island

Prince Edward Island's Department of Transportation and Infrastructure Renewal, at present, uses the Ontario Bridge Management System (OBMS). However, the department is in the process of switching to a new system called BMS2010 very soon.

4.3.9. Nova Scotia

Nova Scotia Transportation and Infrastructure Renewal had been using a version of the Ontario Bridge Management System (OBMS), but due to numerous issues with the program and overall dissatisfaction; the department has stopped implementing it in Nova Scotia, and a new custom program, which is tailored to the department's needs and requirements, is being planned. This system is not yet functional. The proposed new system is called BMS 2010. At present, bridge-inspection information is processed and input into the OBMS that will soon be downloaded into BMS 2010 (latest version). This information is used to create the Bridge Condition Index (BCI). Nova Scotia Transportation and Infrastructure Renewal uses the BCI rating for monitoring and prioritizing bridge repairs and replacements.

4.3.10. Yukon

The Yukon Territory uses the Alberta province system for calculating the sufficiency rating of each bridge. Calculations are undertaken once a year, following inspection of half the bridge inventory. Each bridge is inspected once every 2 years. This system is not a full and comprehensive Bridge Management System.

4.3.11. Northwest Territories

Northwest Territories is in the process of acquiring a full BMS. At present they use the Alberta province system for calculating the sufficiency rating of each bridge. Calculations are undertaken once a year. Each bridge is inspected once every 2 years.

4.3.12. Nunavut

Nunavut does not have highways or road access between communities. Air traffic is the major means of transportation between the various communities. The government of Nunavut only owns two bailey bridges that are located in Arctic Bay. It does not have a BMS. External consultants are hired to do inspections as and when required.

4.4. Types and Frequency of Bridge Inspection

The standard questionnaire which was sent to provincial and territorial governments specified 7 types of inspections (initial, cursory, visual, routine, detailed, underwater, or other) and frequency of inspection (biannually (twice a year), annually, every two years, every three years, every four years, every five years, or other). Provinces/Territories were required to check the ones they undertake. The results are summarized in Tables 9 and 10.

Table 9: List of Types of Bridge Inspections by Provincial/Territorial Agencies

| Province/Territory | Initial | Cursory | Visual | Routine | Detail | Underwater | Other |
|-----------------------|---------|---------|--------|---------|--------|------------|-------|
| British Columbia | | √ | √ | √ | √ | √ | √ |
| Alberta | | | √ | √ | √ | | |
| Saskatchewan | | | √ | √ | | | |
| Manitoba | | | √ | √ | √ | | |
| Ontario | √ | √ | √ | √ | √ | √ | |
| Quebec | | | √ | √ | √ | √ | √ |
| New Brunswick | √ | √ | √ | √ | √ | √ | |
| Prince Edward Island | √ | √ | √ | √ | √ | √ | |
| Nova Scotia | √ | √ | √ | √ | √ | √ | |
| Yukon Territory | √ | | √ | √ | √ | √ | |
| Northwest Territories | | | √ | √ | √ | | |

As can be seen from Table 9 Alberta, Saskatchewan, Manitoba, and the Northwest Territories do not perform underwater bridge inspection. Bridge scour is one of the three main causes of bridge failure. It has been estimated that 60% of all bridge failures result from scour and other hydraulic-related causes. It is the most common cause of highway bridge failure in the United States [23]. All the provinces and territories perform visual and detail inspection.

As shown in Table 10, there are four different types of manuals that document bridge-inspection processes: *British Columbia’s Bridge Inspection Manuals, Books 1, 2, and 3*, dated 1994; *Alberta’s Bridge Inspection and Maintenance (BIM) Manual Version 3.0*, dated 2005; *Quebec’s Manuel d’inspection des structures – Instruction techniques*; and *Ontario’s Ontario Structure Inspection Manual (OSIM)*. OSIM is the most used inspection manual in the country because six provinces (Saskatchewan, Manitoba, Ontario, New Brunswick, Prince Edward Islands, and Nova Scotia) are undertaking their bridge inspections based on this manual. Alberta’s *Bridge Inspection and Maintenance (BIM)* manual is currently being used by Yukon Territory, and the Northwest Territories.

Table 10: List of Frequency of Bridge Inspections by Provincial/Territorial Agencies

| Province/Territory | Inspection Type | Inspection Frequency | Manuals |
|--------------------|------------------------------|---|--|
| British Columbia | Routine Inspections (visual) | Annual | Bridge Inspection Manuals – Books 1, 2, and 3 dated 1994 |
| Alberta | Level 1 (visual) | Major Provincial Highways: 21 months Secondary Provincial Highways: 39 months Local Roads - Standard bridges & culverts: 57 months and Major bridges: 39 months | Bridge Inspection and Maintenance (BIM) Inspection Manual Version 3.0 dated 2005 |

Table 10 (continued): List of Frequency of Bridge Inspections by Provincial/Territorial Agencies

| Province/Territory | Inspection Type | Inspection Frequency | Manuals |
|-----------------------|----------------------------|----------------------|--|
| Saskatchewan | Detailed Visual | Every 2Years | OSIM |
| Manitoba | Detailed Visual | Every 2Years | OSIM |
| Ontario | Detailed Visual | Every 2Years | OSIM |
| Quebec | General Inspections | 2 to 4 Years | Manuel d'inspection des structures – Instructions techniques |
| New Brunswick | Regular Bridge Inspections | Every 2Years | OSIM |
| Prince Edward Islands | Detailed Visual Inspection | N/A | OSIM |
| Nova Scotia | Detailed Visual Inspection | 1 to 5 Years | OSIM |
| Yukon Territory | Level 1 (visual) | Every 2Years | BIM |
| Northwest Territories | Level 1 (visual) | Every 2Years | BIM |
| Nunavut Territory | | As Required | |

4.4.1. British Columbia

British Columbia's Ministry of Transportation and Infrastructure (BC MoT) has a multi-level inspection process. The details are as follows.

- **Maintenance Contractor Inspections:** The BC MoT has privatized the maintenance of the provincial highway system. The BC MoT maintenance contractors, a private sector company, are required to stop and observe structures frequently; depending on the type of structure and the highway class the structure serves. These visits identify hazardous conditions and obtain sufficient information to prioritize structure maintenance. The frequency of inspection varies depending on the type of structure and the type of roadway. The bridge-inspection frequency varies from every 14 days (e.g., Bailey bridges on main highways) to once every year (e.g., steel and concrete bridges on a low-volume side road).
- **Routine Inspections (visual):** This inspection is undertaken by BC MoT's in-house Area Bridge Managers (AMBs) annually (every bridge to be inspected once every calendar year) in accordance with BC MoT's *Bridge Inspection Manuals – Books 1, 2 and 3* dated 1994. The scope of these inspections is to visually inspect as much of the bridge as possible using foot access on the ground and on the bridge deck augmented by the use of binoculars. Bridge inspections by AMBs are more thorough, more systematic, and better documented than maintenance contractor inspections. It is the responsibility of the bridge inspector to document the results of the inspection. The documentation that makes up the inspection reporting system includes:
 - Field notes;
 - Sketches and photographs; and
 - The Bridge Inspection Form.

The results from these routine inspections are the primary source of inspection data entered into the MoT Bridge Management Information System (BMIS).

- Detailed Inspections: MoT's in-house AMBs and the inspection crew also conducts more detailed visual inspections of bridges in accordance with MoT's *Bridge Inspection Manuals – Books 1, 2, and 3* dated 1994. There is no current requirement regarding the frequency of these detailed inspections, but a period of once every five years is suggested. Detailed inspections use access equipment to get close to all parts of a bridge so that small defects, such as steel-fatigue cracks, can be detected.

MoT also carries out the following inspections to supplement the above-mentioned inspections to address areas of specific concern:

- Hydrographic Surveys: There are approximately 100 bridges that get hydrographic surveys, and these inspections are done, on average, about once every 5 years for each bridge. (On average, about 20 hydrographic surveys are done per year.) This inspection is carried out for scour critical bridges.
- Underwater Diving Inspections: There are approximately 25 bridges that get diving inspections, and these examinations are done, on average, about once every 5 years for each bridge. (On average, about 5 diving inspections are done per year.) This inspection is carried out for scour critical bridges and bridges that have components that are permanently underwater.
- Bridge Deck Condition Surveys: Approximately, 30-50 surveys are done per year.
- Special Inspections and Testing to Further Investigate Specific Issues of Concern: These inspections are done as required.

4.4.2. Alberta

Alberta Transportation has the following two levels of bridge inspection:

Level 1: It is a general inspection (detailed visual inspection) which requires completion of the Bridge Inspection and Maintenance (BIM) report and the use of basic tools and equipment in accordance with *BIM Inspection Manual Version 3.0* dated 2005. This level of inspection is undertaken by certified bridge inspectors and performed at time intervals not exceeding the following [23].

- Major Provincial Highways: 21 months
- Secondary Provincial Highways: 39 months
- Local Roads: Standard bridges and culverts, 57 months, and major bridges, 39 months

Level 2: It is an in-depth inspection which requires completion of the BIM report; the appropriate Level 2 reports; and the use of specialized tools, techniques, and equipment in accordance with *BIM Inspection Manual – Level 2 – Version 1.1* dated 2007. Certified bridge inspectors, who have the specialized knowledge or training, undertake this inspection at time intervals not exceeding the following [24].

- Concrete Deck Inspection: 4-6 year cycle
- Copper Sulphate Electrode Testing: 4-6 year cycle
- Chloride Testing: 4-6 year cycle
- Ultrasonic Truss Inspections: 4-6 year cycle
- Culvert Barrel Measurements: As recommended from a Level 1 inspection
- Timber Coring: As recommended from a Level 1 inspection
- Other in-depth inspections are carried out as-required basis; e.g., detailed scour surveys are performed after a significant flood event.

Most major bridges, standard bridges, and culverts are adequately inspected by a certified bridge inspector on a routine basis (Level 1). However, certain major bridges or components of

standard bridges and culverts require inspection with specialized knowledge, tools and equipment. Almost all bridges will require at least two specialized inspections (Level 2) during their lifespan. Specialized inspection includes ultrasonic tests on steel, Copper Sulfate Electrode (CSE) tests on deck concrete, coring of timber caps and/or corbels, etc. Level 2 inspections are essential for high load and overload damage, flood damage, or where critical or significant deficiencies are known or suspected [24].

A standard bridge is defined as a bridge constructed according to departmental standard drawings (plans). These bridges are suited for non-complex site conditions and can be put together very quickly. Timber and short-span concrete bridges are examples of standard bridges [24].

A major bridge is defined as a bridge that does not fit the standard-bridge category due to the length and height requirements for the bridge or other site conditions. Truss bridges, steel girder bridges, and longer-span concrete bridges are examples [24].

4.4.3. Saskatchewan

The Saskatchewan Ministry of Highways and Infrastructure has the following bridge inspection policy.

- **Major Structures:** This category includes major river crossings, overpass structures, and non-typical structures. Major structures receive a detailed visual inspection, conducted biennially in accordance with the OSIM guidelines.
- **Minor Structures:** This category primarily includes standard timber and precast structures of smaller span lengths. Minor structures also receive a detailed visual inspection, conducted biennially in accordance with the OSIM guidelines.

- Annual Routine Inspections: In addition to standard inspections, the ministry staff responsible for day-to-day road maintenance also provides a brief visual inspection of bridge structures, primarily to identify obvious safety concerns. Inspections are usually performed after the spring flood event.
- Specialized Inspections: Specialized inspections are detailed deck survey of all structures containing a concrete deck without a waterproofing membrane. These inspections are done on a 4-year rotation and include half-cell testing and chain drags.
- Non-Destructive Testing (Ultrasound, radiograph, or dye-penetrant): This testing is done on structural steel with known fatigue-prone details.

4.4.4. Manitoba

Manitoba Infrastructure and Transportation (MIT) has a multi-level inspection process; below, are the details.

- Routine Inspections (Level I): MIT utilizes regional maintenance staff to undertake routine inspections annually (every bridge to be inspected once every calendar year). The scope of these visual inspections is to identify potential safety concerns that need immediate attention and to assist in the development of MIT's Maintenance/Preservation/Capital Program.
- Detailed Inspections (Level II): The MIT Water Control & Structures staff and consultants carry out the more detailed visual inspections following the MIT inspection policy schedule based on a MIT-modified OSIM. The OSIM states that “ a detailed visual inspection is an element-by-element ‘close-up’ visual assessment of material defects, performance deficiencies and maintenance needs of a structure” [25]. Basically, these inspections are conducted within arms’ length of the element utilizing inspection tools

(i.e., hammer, dye penetrant, pocket knife, ice pick, increment borer for boring timber elements, etc.) and may require the use of MIT's under-bridge cranes to access the specific elements to be inspected. The frequencies of inspections are as follows.

- All Major Bridges on Provincial Trunk Highways (PTH): 24 months
- Major Bridges on Provincial Roads and Main Market Roads: 48 months
- Minor Bridges on Provincial Roads, Main Market Roads, Access Roads, and Service Roads: 72 months.

“Major” refers to bridges that are over 6 m in length. The above-mentioned intervals are guidelines to be adhered to within reasonable limits. Shorter intervals may be required, depending on various factors such as age, known deficiencies, increased traffic volumes and others.

- Detailed Condition Surveys (Level III): The MIT Water Control & Structures staff and consultants are presently responsible for completing detailed condition surveys. Detailed condition surveys are conducted on structures that have been identified for rehabilitation or on an as-needed basis. Detailed condition surveys of concrete components are completed based on a MIT-modified Ontario Structure Rehabilitation Manual (OSRM).

4.4.5. Ontario

The Ministry of Transportation of Ontario (MTO) has the following inspection policy:

- Detailed Inspections: Detailed visual inspection of all bridges is required every 2 years in accordance with the Ontario Structure Inspection Manual (OSIM) as stated under the Public Transportation and Highway Improvement Act, Ontario Regulation 104/97 (Amended to 106/02). This inspection is done by, or under the direction of, a Professional Engineer. This inspection is an element-by-element, “close-up” visual assessment.

“Close-up” is defined as “a distance close enough to determine the condition of the element”[25].

- Annual Maintenance Inspections: Maintenance contractors perform annual maintenance inspections and record the defects on a checklist-type form. During this inspection, the following steps are taken:
 - Checking the general condition of the bridge.
 - In instances when there is a safety issue, the inspector immediately calls in a repair crew to fix the problem.
- Routine Drive-by Inspections by Maintenance Contractors: MTO has privatized maintenance. Maintenance contractors are required to observe structures during their road patrols daily, weekly, or somewhere in between based on the traffic volumes.
- Specialized Investigations: These inspections include detailed deck or substructure condition surveys, detailed coating surveys, underwater investigations, fatigue investigations, seismic investigations, and structure evaluations.

4.4.6. Quebec

The Transport Quebec (MTQ) inspection program includes both routine inspection and ad-hoc inspection. Bridge inspections are undertaken in accordance with the “*Manuel d’inspection des structures – Instructions techniques*”. The following are routine inspections:

- General inspections,
- Annual inspections.

The following are ad-hoc inspections:

- Underwater inspections,

- Special inspections,
- Evaluation inspections,
- Scouring inspections,
- Visual inspection.

In addition, when a decision is made to perform work on a structure, a comprehensive damage survey is prepared at least 2 years before the commencement of work. Table 11 summarizes MTQ’s bridge inspection program.

Table 11: MTQ’s Inspection Frequencies

| Type of inspection | Brief description | Frequency |
|--------------------|--|--|
| General | Applies to all structures covered by the inspection program. It involves a systematic examination of all components for a structure, with a view to detect defects and to evaluate their effect on the capacity, stability, and service life of the structure and on the user’s comfort and safety. | 2 to 4 years |
| Annual | Applies to all structures covered by the inspection program. It involves a visual examination of the structure components in order to identify, as quickly as possible, all anomalies and obvious defects that can cause traffic accidents or affect the capacity or stability of the structure. | Annual |
| Underwater | Applies to structures where some components of the foundation cannot be inspected in a conventional manner because of the water depth. The engineer in charge identifies these structures. It involves examination of the underwater portion of the foundation elements by certified divers in order to detect defects that can affect the capacity or stability of the structure. | As determined by an engineer, but 10 years max |
| Special | May be required for structures with a complex structural system or if major defects are detected in the main components of a structure during the general inspection or after vehicle impacts on the structures. | As needed |
| Evaluation | These inspections are part of the process of evaluating the load-carrying capacity of structures. These inspections involve a meticulous examination of the main components of a structure in order to detect any defects and to assess their affect on the load-carrying capacity of these components in relation to the structure as a whole. | As needed |
| Visual | Applies to structures with low assessed theoretical load-carrying capacity that do not show any sign of weakness and for which the anticipated fracture mode is ductile. Involves examining the components in order to detect any new defects that may appear as quickly as possible and to monitor their development. | As needed |

4.4.7. New Brunswick

The New Brunswick Department of Transportation (NBDOT) undertakes the following bridge inspections.

- Routine visual inspections: This inspection is undertaken by the district bridge maintenance personnel to identify hazardous or potentially hazardous conditions during the normal course of their work.
- Regular bridge inspections: All bridges in New Brunswick, except the privately owned bridges, are inspected by the NBDOT in-house staff. In-service bridges are inspected biennially as per the Ontario Structures Inspection Manual (OSIM).
- Structural analysis: In-depth detailed structural analyses are undertaken by structural engineers (in-house or consultants) as required.
- Supplementary inspections are conducted by structural engineers when deficiencies identified during regular inspections warrant further investigation.
- Bridge deck condition surveys are undertaken as required (approximately 8 bridges per year).

4.4.8. Prince Edward Island

Prince Edward Island's Department of Transportation and Infrastructure Renewal has a multi-layered inspection process. Bridges are inspected in accordance with the OSIM. The following details are used:

- Road supervisors identify any potential issues on an ad-hoc basis.
- An in-house inspection crew carries out a visual walk around on a triennial basis.
- Detailed visual inspections are done as required by the walk-around inspection.

- Underwater inspections are done about once every 5 years or more frequently, depending on the structure.
- Deck testing on larger, more used bridges is done as required.

4.4.9. Nova Scotia

Nova Scotia's Transportation and Infrastructure Renewal (TIR) has a bridge inspection policy which outlines what inspections are done for various bridges. Factors which affect the type of inspection, the extent to which the bridges are inspected, as well as the frequency of inspections on the condition of the bridge, the classification of the road, the results of previous inspections, and the type of bridge:

- Level 1 Inspection: This yearly walk-around inspection is done on all bridges in Nova Scotia by Operation Supervisors in each district. A Level 1 inspection is done for all structures on a yearly basis.
- Level 2 Inspection: This detailed visual inspection is performed by qualified inspectors in accordance with the OSIM. A Level 2 inspection is carried out based on the condition of the structure as per the last Level 2 inspection report. If the condition is reported as good, re-inspection is in 4 to 5 years; if it is fair condition, re-inspection is in 2 to 3 years; and if it is poor condition, re-inspection is in 1 year.
- Level 3 Inspection: This detailed inspection is performed by a qualified structural engineer. There is no fixed time frequency for this inspection. The inspection frequency is determined according to need as when directed by the engineer.
- Nova Scotia also carries out specialized inspections, such as underwater inspections, bridge deck condition surveys, and non-destructive testing.

4.4.10. Yukon

Highways and Public Works, Government of Yukon undertakes the following bridge inspections in accordance with the Alberta Transportation's *Bridge Inspection and Maintenance* (BIM) Manual.

- Level 1: This general inspection (visual inspection) requires the completion of the Bridge Inspection and Maintenance (BIM) report and the use of basic tools and equipment in accordance with the *BIM Inspection Manual*. This level of inspection is performed biannually.
- Detailed inspections (sometimes, including non-destructive testing) are always undertaken ahead of major rehabilitation design. Such inspections are done by consulting engineering firms outside the Yukon, following a Request for Proposal (RFP) competition.

4.4.11. Northwest Territories

Department of Transportation, Government of Northwest Territories undertakes the following bridge inspections in accordance with the Alberta Transportation's *Bridge Inspection and Maintenance* (BIM) Manual.

- Level 1: This general inspection (visual inspection) requires the completion of the Bridge Inspection and Maintenance (BIM) report and the use of basic tools and equipment in accordance with the BIM Inspection Manual. This level of inspection is performed triennially.
- Detailed inspections are undertaken ahead of major rehabilitation design or as required by the consulting engineering firms.

4.5. Hands-On/Close-Up Inspection

Table 12 summarizes responses about hands-on/close-up inspection by provinces and territories. Hands-on/close-up inspection is defined as physically touching and sounding all elements of a bridge. This inspection may require lane closure and the use of an under-bridge inspection vehicle. Alberta and the Northwest Territories do not perform hands-on/close-up inspection on their bridges.

Table 12: Hands-on/Close-up Inspection by Provinces

| Province/Territory | Perform Hands-on/Close-up Inspection |
|-----------------------|--------------------------------------|
| British Columbia | Yes |
| Alberta | No |
| Saskatchewan | Yes |
| Manitoba | Yes |
| Ontario | Yes |
| Quebec | Yes |
| New Brunswick | Yes |
| Prince Edward Island | Yes |
| Nova Scotia | Yes |
| Yukon Territory | Yes |
| Northwest Territories | No |

4.6. Condition Rating

Condition rating is a way of describing, in general terms, the influence of a defect on a structural member or on the bridge as a whole. It is purely subjective, and its accuracy depends on the ability and experience of the inspector. In spite of subjectivity, the idea is adopted throughout the world, and it takes the form of a numerical indicator [12].

As mentioned in section 5.2. Types and Frequency of Bridge Inspection, there are four different types of manuals that document bridge-inspection processes in Canada namely British Columbia’s Bridge Inspection Manuals; Alberta’s Bridge Inspection and Maintenance (BIM); Quebec’s Manuel d’inspection des structures – Instruction techniques; and Ontario’s Ontario Structure Inspection Manual (OSIM). Each inspection manual has its own condition rating system. Therefore there are four condition Rating systems. British Columbia uses 1 (Excellent) to 5 (Very Poor); Alberta uses 1 (Immediate Action) – 9 (Very Good); Ontario uses Excellent, Good, Fair, and Poor; and Quebec system is explained in Section 5.4.4. Table 13 summarizes the condition-rating scales for the provinces and territories. All four condition rating scales are explained in the subsequent subsections.

Table 13: Condition Rating Scale of Provinces/Territories

| Province/Territory | Inspection Condition Rating Scale |
|-----------------------|---|
| British Columbia | 1 (Excellent) to 5 (Very Poor) plus not inspected |
| Alberta | 1 (Immediate Action) – 9 (Very Good) |
| Saskatchewan | Excellent, Good, Fair, and Poor |
| Manitoba | Excellent, Good, Fair, and Poor |
| Ontario | Excellent, Good, Fair, and Poor |
| Quebec | Varies See Section 5.4.4. |
| New Brunswick | Excellent, Good, Fair, and Poor |
| Prince Edward Island | Excellent, Good, Fair, and Poor |
| Nova Scotia | Excellent, Good, Fair, and Poor |
| Yukon Territory | 1 (Immediate Action) to 9 (Very Good) |
| Northwest Territories | 1 (Immediate Action) to 9 (Very Good) |

4.6.1. British Columbia

Table 14 summarizes the British Columbia Ministry of Transportation and Infrastructure’s (BC MoT) general condition rating system. BC MoT requires the inspector to record an explanation of the problem each time the condition state is poor or very poor, or when the component cannot be inspected.

Table 14: British Columbia General Condition States

| Rating | | Commentary |
|--------|----------------|---|
| 1 | Excellent | As-new condition. |
| 2 | Good | Normal wear and deterioration not requiring maintenance or repair. |
| 3 | Fair | Minor defects, deterioration, or collision damage; generally requires maintenance or repair. |
| 4 | Poor | Advanced deterioration, significant defects, or collision damage; repair required. |
| 5 | Very Poor | Serious defects, deterioration, or collision damage; imminent failure of (a) component(s) requiring immediate repair or replacement and/or load restrictions. |
| | Not Applicable | Used when that component is not present on the structure. |
| | Cannot Inspect | |

4.6.2. Alberta

The bridge inspection and maintenance (BIM) system was developed by Alberta Transportation. This system is also used by the Yukon and Northwest Territories. A brief description of the condition rating system is given in Table 15. It consists of a numerical rating range of 1 to 9. This rating applies to all inspection elements as well as the general rating for each category. The rating is representative of the element condition and the ability of the element

to function as originally designed. The rating does not consider the standard of the element compared to current design standards. For instance, a substandard bridge-rail can be rated 9 if it is in excellent condition [24].

The rating of an element is determined by the rating of the worst item within the group. It is not intended to be an overall representation of the condition and functionality of all the items. For instance, a bridge may have 15 bridge-rail posts with only 1 that is broken and rated 3. In this case even though the other 14 posts are in good condition and rated 5 or more, the rating for the “Bridge-rail Posts” element is 3 [24].

Blank ratings are not allowed on the form. Each element is assigned a rating of 1 through 9, N, or X. The rating of the element is based on what the inspector can see. The inspector should be able to see enough of the element to be comfortable assigning a rating. If the element is inaccessible or enough is not visible for the inspector to confidently assign a rating, the element is rated N. If a particular element does not apply to the structure being inspected, the element is rated X [24].

4.6.3. Ontario

The Structural Inspection Manual (OSIM) was developed by Ontario. However, five other provinces (Saskatchewan, Manitoba, New Brunswick, Prince Edward Island, and Nova Scotia) also use this system.

The OSIM defines four Condition States for bridge elements: Excellent, Good, Fair, and Poor. The condition of bridge elements is defined to be in any one or more of these Condition States. At any given time, areas within a bridge element may be in different Condition States, or the whole element may be in the same Condition State.

Table 15: Alberta Bridge Inspection and Maintenance System (BIM) Condition Rating System [24]

| Rating | | Commentary | Maintenance Priority |
|--------|------------------|---|---|
| 9 | Very Good | New condition | No repairs in foreseeable future |
| 8 | | Almost-new condition | No repairs in foreseeable future |
| 7 | Good | Could be upgraded to new condition with very little effort. | No repairs necessary at this time. |
| 6 | | Generally good condition. Functioning as designed with no signs of distress or deterioration. | No repairs necessary at this time. |
| 5 | Adequate | Acceptable condition and functioning as intended. | No repairs necessary at this time. |
| 4 | | Below minimum acceptable condition. | Low priority for repairs. |
| 3 | Poor | Presence of distress or deterioration. Not functioning as intended. | Medium priority for replacement, repair, and/or signing. |
| 2 | | Hazardous condition, severe distress, or deterioration. | High priority for replacement, repair, and/or signing. |
| 1 | Immediate Action | Danger of collapse and/or danger to users. | Bridge closure, replacement, repair, and/or signing required as soon as possible. |
| N | Not Accessible | Element cannot be visually inspected. | |
| X | Not Applicable | Element not applicable to this bridge. | |

For each bridge element, the inspector assesses and records the amount (area, length, or unit as appropriate) of the element in each of the four Condition States. This assessment is based predominately on visual observations, however, some non-destructive testing, such as hammer

tapping of concrete for delamination, will be required to determine or verify areas in poor condition [25]. The average for each of these conditions determines the condition of the element, and a weighted average of all elements determines a single number from 0 to 100 for the bridge (Practically, the number is between 40 and 100.). As a general rule of thumb, the following philosophy is used for most Condition State tables [25]:

- Excellent: refers to an element (or part of an element) that is in “new” (as constructed) condition; No visible deterioration-type defects are present, and remedial action is not required. Minor construction defects do not count as visible deterioration-type defects.

Examples:

- “bug holes” in concrete barrier walls
- well-formed patina in atmospheric corrosion resistant (ACR) steel girders
- Good: refers to an element (or part of an element) where the first sign of “light” (minor) defects are visible. This usually occurs after the structure has been in service for a number of years. These types of defects would not normally trigger any remedial action because the overall performance of the element is not affected.

Examples:

- Light corrosion (no section loss)
- Light scaling
- Narrow cracks in concrete
- Light decay in wood
- Fair: refers to an element (or part of an element) where medium defects are visible. These types of defects may trigger a “preventative-maintenance” type of remedial action (e.g., sealing, coating, etc) where it is economical to do so.

Examples:

- Medium corrosion (up to 10% section loss)
- Medium cracks in concrete
- Poor: refers to an element (or part of an element) where severe and very severe defects are visible. In concrete, any type of spalling or delamination would be considered “poor” because these defects usually indicate more serious underlying problems in the material (e.g., corroding the reinforcing steel). These types of defects would normally trigger rehabilitation or replacement if the extent and location affect the overall performance of that element.

Examples:

- Severe corrosion (greater than 10% section loss)
- Spalling, delaminations, etc.

4.6.4. Quebec

Quebec’s condition rating is based on the results of the general inspection. The structure management system calculates various indices. The condition index, or IES, is calculated based on the information regarding the condition of the structure’s materials entered in the system (material condition: A, B, C, or D). The performance index, or ICS, is calculated based on the performance ratings attributed to the structure’s various elements (the performance condition varies from 4 to 1). The functionality index, or IFS, takes into account, among other things, the type of structure, the bearing capacity factor (F), the signage, and the width of the structure. The maximum value for each index is 100. The greater the index value, the better the condition of the structure.

4.7. Personnel Qualifications

Table 16 summarizes the requisite qualifications of the inspection staff. Manitoba and the Northwest Territories do not have certification programs. Ontario has an inspection-training program that is required for inspectors, who do work for the ministry. It can be said that Ontario does not have a certification program.

Table 16: Provincial/Territorial Qualifications for Inspection Staff

| Province/Territory | Are bridge inspectors formally certified? | If yes, who certified them? | Are there any re-qualification and re-certification requirements? | Are educational and physical qualifications required of inspectors? | Who sets requirement? | How often inspectors are trained? | Who trains them? |
|-----------------------|---|-----------------------------|---|---|-----------------------|-----------------------------------|----------------------|
| British Columbia | Yes | Province | No | Yes | Province | Every 2 Years | Province |
| Alberta | Yes | Province | Yes | Yes | Province | Every 5 Years | Province |
| Saskatchewan | Yes | Province | No | Yes | Province | In-house training | Province |
| Manitoba | No | | No | Yes | | As Required | Province |
| Ontario | No | | | | | Every 2 Years | |
| Quebec | Yes | Province | Yes | Yes | Province | In-house training | Province |
| New Brunswick | Yes | Province | Yes | Yes | Province | Every 2 Years | Outside sources |
| Prince Edward Island | Yes | Province | Yes | Yes | Province | Every 5 Years | Province |
| Nova Scotia | Yes | FHWA | Yes | Yes | Province | | Province |
| Yukon Territory | Yes | Province | No | Yes | Province | When Required | Province |
| Northwest Territories | No | | No | Yes | | Every 5 Years | External Consultants |

Provinces that offer certification programs certify the inspectors themselves, except in Nova Scotia. The U.S. Department of Transportation Federal Highway Administration (FHWA) certifies inspectors in Nova Scotia. In provinces that have certification programs, only British Columbia, Saskatchewan, and the Yukon Territory do not have re-certification requirements.

In British Columbia maintenance contractor inspections are undertaken by the bridge foreman or the bridge crew. BC MoT inspectors are certified using in-house training course and testing. District Area Bridge Managers (ABMs) perform most of the inspections. They report to the District Transportation Managers. (there are 11 District offices). There are 3 Regional offices each with a bridge engineering section. The Regional bridge engineering sections work with the ABMs. BC MoT also has a dedicated inspection crew in Burnaby that carries out mostly detailed inspections. Private consultants are hired for special inspections [34].

In Alberta Level 1 inspections on standard bridges and culverts are carried out by Class B certified bridge inspectors. Level 2 Inspections are done under the direction of certified Class A inspectors. Both Class A and Class B bridge inspectors are certified through Alberta Transportation by using in house courses and testing [34].

In Saskatchewan minor bridges are inspected by a 2 person team. The lead inspector is part of the permanent in house staff and is OSIM trained. The second inspector is a term student. For major bridges the inspection teams are required to be teams of 2 with the lead inspector being either a registered professional engineer or engineering technologist with a minimum of 5 years of bridge inspection experience and have completed a recognized certified bridge inspection course preferably with OSIM experience. If the lead inspector is an engineering technologist, he/she must report directly to a registered professional engineer [34].

In Ontario maintenance inspectors must have the following qualifications: "...shall have knowledge of structure maintenance practices and aware of problems that arise from weathering, overloading and unusual behavior of structure components. This knowledge is gained from a minimum of three years hands on experience... in Canada" [34]. The qualifications requirements for detailed visual inspectors are a successful completion of MTO bridge inspection course

(every two years, which includes in-class & field work) and several years of bridge inspection experience. Detailed visual inspections must be performed under the direction of a professional engineer. Currently about 50% of inspections are done by in-house staff and 50% by private consultants. Private consultants are used for special inspections such as underwater inspections, NDT inspections, deck condition surveys, and inspections requiring more detailed levels of effort than those carried out in-house [34].

In Quebec there are five classifications of bridge inspector that have been established for MTQ personnel: A2 and A1, for engineers; B2 and B1, for technicians; and Classification C. Inspectors holding classifications A and B can carry out general or summary inspections, while inspectors holding classification C can carry out only summary inspections. All inspectors must undergo classroom training related to the inspection of structures. MTQ inspectors must also take part in on-the-job field training. Engineers from private firms must have a certain amount of experience related to bridge structures [34].

In Nova Scotia Level 1 inspections are performed by the operation supervisors, who are trained by the respective District Bridge Engineer in their district. Level 1 inspectors report to the Bridge Engineer in their District. The Bridge Engineer will report to the Bridge Office about any major concerns noted in the inspection. Level 2 inspections are performed by bridge inspectors, who must be qualified by FHWA training for this position. Level 2 inspectors report to the Bridge Engineer in their District. Level 3 inspections are performed by a qualified structural Engineer. In house staff performs all Level 1 and Level 2 inspections. A level 3 inspection may be carried out by in house staff or by a private consultant [34].

In New Brunswick regular bridge inspections are performed by Head Office Bridge Inspectors. The inspectors are certified engineering technicians and have received on the job

training. They also have received classroom training on the FHWA Bridge Inspection Training Manual. The inspectors are currently registered for a one week training course on OSIM. The inspectors report to the Bridge Maintenance Engineer, who reviews the bridge inspection reports with them on a weekly basis. There are 6 District Offices in the province. The Bridge Maintenance Superintendents report to the Assistant District Engineer who reports to the District Engineer. The Districts report to the Executive Director of Operations in Head Office. Problems and issues discovered with bridges are directed to the Bridge Maintenance Engineer or the Assistant Director of the Bridge Section of Maintenance & Traffic Branch. The issues requiring engineering review are forwarded to the Design Branch. Private consultants are used for special inspections including detailed structural analysis [34].

In Prince Edward Island private consultants and two in-house groups, one for bridges, the other for smaller culvert structures carry out bridge inspections. These individual inspection groups ultimately report to the Engineering Manager. Bridge inspectors must have had a two week inspection course, developed by the Department, and must be certified inspectors. The Certification process involves attending the course, writing the final exam and inspecting three exam bridges [34].

All the provinces and territories have educational and physical qualifications requirements for inspectors. In Nova Scotia, inspectors must have a combination of training and education to meet the job requirements, which typically includes post-secondary education, with previous inspection experience or the willingness to obtain the required certification and training. Other training includes confined spaces, Occupational Health & Safety, first aid, working at heights, traffic control, and others. Physical requirements include working at heights and could include confined spaces. Training varies from two to five years.

4.8. Equipment

Bridges do not only age, but also experience changes in harsh environmental conditions, freeze-thaw-heat cycles, excessive precipitation events, and an increase in traffic and heavy loads putting more stress and strain on them than originally intended. Bridge engineers need a reliable way to assess the structural integrity of bridges to maintain the continuous operation of the road network while ensuring the safety of the public. Traditional visual inspection techniques are both time consuming and expensive. They are also qualitative and can only assess outward appearance. Any internal damage may go unnoticed for a long period of time. Structural health monitoring systems can detect changes in the bridge superstructure and, in some cases, predict impending failures. These systems can monitor bridges in real time and warn engineers about possible problems to avoid tragedies like the I-35W collapse in August 2007 [26]. Moreover, the data can be interoperated and used to make effective decisions.

The standard questionnaire asked to specify types of nondestructive evaluation, nondestructive testing, or other advanced testing equipment currently being utilized; what remote monitoring technologies (if any) are being used to monitor bridges; and if they use structural health monitoring (SHM) as a Bridge Management Tool. The results are summarized in Table 17. Only Quebec and New Brunswick employ structural health monitoring (SHM) as a bridge-management tool.

In Ontario, if anything is suspected based on the visual inspection, more detailed non-destructive tests are then conducted. These tests include half-cell condition survey, fatigue inspection (Mag Particle, Liquid Penetrant, etc.), underwater inspection, coating condition survey, and bridge-load test. Thus, the non-destructive testing methods are used as secondary inspection tools.

Quebec uses the following for special inspection: radar, corrosion potential, thermography, ultrasound, and magnetic particle. In Nova Scotia, remote monitoring has been used on a few select bridges on a trial basis.

Table 17: Provincial/Territorial Utilization of Equipment

| Province/Territory | Is any nondestructive evaluation, nondestructive testing, or other advanced testing equipment used during bridge inspection? | Type of nondestructive evaluation, nondestructive testing, or other advanced testing equipment used | What remote monitoring technologies (if any) are being used to monitor bridges? | Do you use structural health monitoring (SHM) as a Bridge Management Tool? |
|--------------------|--|--|---|--|
| British Columbia | Yes | Chain Drag, Hammer Sounding, Dye Penetrate, Ultrasound, Side-scan Sonar, ½ Cell, Radar, Depth sounding, Tomography, Moisture meters, and Rebar Locators | Strain Gauges Accelerometer | Starting to use it. |
| Alberta | Yes | Chain Drag, Hammer Sounding, Dye Penetrate, Ultrasound, ½ Cell, etc. | N.A. | No |
| Saskatchewan | No | N.A. | N.A. | N.A. |
| Manitoba | Yes | Chain Drag, Concrete Cores, and Chloride Testing | N.A. | N.A. |
| Ontario | Yes | Half-cell condition survey, Fatigue inspection (Mag Particle, Liquid Penetrant, etc.), underwater inspection, Coating Condition Survey, and Bridge-Load Test | Strain Gauges | No |

Table 17 (continued): Provincial/Territorial Utilization of Equipment

| Province/Territory | Is any nondestructive evaluation, nondestructive testing, or other advanced testing equipment used during bridge inspection? | Type of nondestructive evaluation, nondestructive testing, or other advanced testing equipment used | What remote monitoring technologies (if any) are being used to monitor bridges? | Do you use structural health monitoring (SHM) as a Bridge Management Tool? |
|-----------------------|--|---|---|--|
| Quebec | Yes | radar, corrosion potential, thermography, ultrasound, and magnetic particle | Strain Gauges Accelerometer | Yes |
| New Brunswick | Yes | Viewing tubes and explorer cameras | Strain Gauges Tilt Sensors Accelerometer | Yes |
| Prince Edward Island | No | N.A. | | No |
| Nova Scotia | Yes | | Strain Gauges | No |
| Yukon Territory | No | N.A. | None | No |
| Northwest Territories | Yes | Ultrasonic | None | No |

4.9. Documentation

The results of a bridge inspection must be documented clearly, completely and accurately. The success of a bridge inspection program is dependent upon this documentation and reporting system. It is essential that the use of the reporting system is uniform in order to eliminate disparity and differing standards across the system [35].

The standard questionnaire asked if they have standard inspection forms and report formats, process of distribution, review, and evaluation for inspection reports, reviewer of the inspection reports, and length (time) inspection records being kept. The results are summarized in Table 18.

Table 18: Provincial/Territorial Bridge Inspection Documentation

| Province/Territory | Do standard inspection forms and report formats exist? | If yes, how many different types? | What is the process of distribution, review, and evaluation for inspection reports? | Who reviews the inspection reports? | How long are inspection records kept? |
|-----------------------|--|-----------------------------------|--|-------------------------------------|---|
| British Columbia | Yes | 5 | Entered into BMIS. Accessible by engineers | Bridge Engineer Other Inspector | Forever |
| Alberta | Yes | 25 | | Bridge Engineer | Forever |
| Saskatchewan | Yes | 2 | Inspection reports submitted to engineer for review | Bridge Engineer | Forever |
| Manitoba | Yes | 3 | | Bridge Engineer | Sometimes longer than the life of the bridge depend on the circumstances. |
| Ontario | Yes | 2 | | Bridge Engineer | Life of the Bridge |
| Quebec | Yes | | | Bridge Engineer | Life of the Bridge |
| New Brunswick | Yes | 1 | Reports are available through BMS | Bridge Engineer | Forever |
| Prince Edward Island | Yes | 1 | Review all reports from the inspectors on an annual basis | Bridge Engineer | Life of the Bridge |
| Nova Scotia | Yes | | Once an inspection is complete, the report is forwarded to District Bridge Engineers for review. They review the report and act on any maintenance requirements as required, and any safety issues are addressed. A summary report is forwarded to their supervisor. | Bridge Engineer | Life of the Bridge |
| Yukon Territory | Yes | 12 | Inspection is done May/June to August/September; field data entry is completed by November/December; hard copy memos are issued by the Bridge Inspector to the Bridge Manager by December/January; review is undertaken by the Bridge Manager, after which the memos are distributed to the Maintenance Branch for minor repair items while the Bridge Manager handles major repairs/rehabilitation/replacement. | Bridge Manager | Life of the Bridge |
| Northwest Territories | Yes | | Inspection reports are submitted to the Structural Assets Manager and then to Head of Structures section for review. | Structural Assets Manager and Head | Life of the Bridge |

In British Columbia the documentation that makes up the inspection reporting system includes:

- field notes – field notes may be required when inspecting large structures with many individual members (e.g. a through truss) or in situations where the structure is badly deteriorated. In either of these situations, it is unlikely that sufficient space is available on the Bridge Inspection Form to provide complete documentation. The inspector should use separate field notes to record the data from the inspection and later summarize this data onto the Bridge Inspection Form. The field notes are an important part of the bridge file and must not be destroyed. The format for setting up field notes is flexible; however, it is preferable that the format is consistent from year to year. The inspector should use whatever system he or she is comfortable with, as long as the notes are complete and legible [35].
- sketches and photographs - Sketches and photographs are generally required to document each inspection. A sketch is used to clarify the location of a defect or deterioration. Sometimes, it is difficult to record the extent and location of the defect using only words. If for example, during an inspection of the wearing surface of a deck, the inspector locates areas of delamination and spalling, a sketch showing the plan view of the deck should be drawn and the delaminated and spalled areas noted on the sketch. North arrow should be drawn on the sketch or sufficient identifying items, such as sidewalks or deck joints, so that it is clear which way the sketch is oriented [35].

Photographs are a very effective way of showing the general overview of a bridge site or to illustrate a particular defect or type of deterioration. A photograph is also required to each situation that results in a condition rating of 4 (poor) or 5 (very poor) [35].

- the Bridge Inspection Form – the Inspection Form is the standard Ministry form used to document and report the results of an inspection of the condition of a structure. The headings on the Bridge Inspection Form are grouped as follows:
 - channel
 - substructure
 - superstructure
 - deck
 - approaches

Each of the above parts is further divided into its main components. Based on the results of the inspection, each component is assigned relevant condition ratings.

The percentage of each relevant condition state is recorded on the inspection form.

The Bridge Inspection Form also contains space to include the following additional information:

- ❖ structure identification -the bridge number and name
- ❖ the date of the inspection and the inspector's name -include also the time, temperature and weather conditions and the names of all inspection personnel

- ❖ inspection explanation or description -comments explaining any rating of poor or very poor -include in this section any special access equipment or non-destructive testing equipment used during the inspection
- ❖ posted weight restrictions
- ❖ posted hazard warning signs
- ❖ a description of the drainage area -water level fluctuation, logging debris, etc.
- ❖ rehabilitation and maintenance work notes -comments describing existing conditions that require maintenance or repair (either immediate or scheduled).

As shown in the Table 18, Alberta has the most (25) standard inspection forms. This includes 13 types of single inspection forms and 12 common types of combination inspection forms, as shown in Table 19 [24]. The province is divided into 4 regions; the Regional Bridge Manager (RBM) responsible for ensuring Level 1 inspections are undertaken; 90% of Level 1 inspections are performed by private consultants. 90% of the Level 2 inspections are undertaken by private consultants also; either on an as need basis through the region or in the cases of specific programs through the head office in Edmonton. The Concrete Deck Testing and Ultrasonic Truss Inspection programs are province wide and are administered through the Bridge Section in head office in Edmonton [35].

In Ontario detailed visual inspections must be performed under the direction of a professional engineer. The head office inspect about 50 bridges a year and compare the results to regional inspection results (both in-house and consultant). A summary report is prepared yearly and results are discussed with individual inspectors[35].

Province of Saskatchewan's in house inspection staff report directly to the preservation engineers. Consultants are managed by and submit reports to the preservation engineers. There is one preservation engineer for each of the three regions of the province. The preservation engineers report directly to the director of bridge services [35].

Table 19: Alberta's Standard Bridge Inspection Forms [24]

| Form Type | Description |
|--|--|
| TH | Through Trusses |
| PT | Pony Truss |
| SG | Rolled Beams Riveted Plate Girders Welded Girders Steel Rigid Frames |
| SS | Other Trusses & Arches |
| DT | Deck Trusses |
| TT | All Timber Bridges |
| PCS | Standard Precast Bridges |
| PSR | Regular Prestress Bridge |
| CON | All Cast in Place Concrete Bridge Concrete Tee Girder Bridges Concrete Flat Slab Bridges |
| CUL1 CULM CULE | Single Culverts Multiple Culverts Culverts extended with different material and/or size |
| SIGN | Sign Structures |
| THTT THPCS THPSR THSG THPT PTTT PTPCS SGTT SGPCS PSRPCS SSSG DTSG | Through Trusses with Timber Approaches Through Trusses with Standard Precast Approaches Through Trusses with Regular Prestress Approaches Through Trusses with Steel Girder Approaches Through Trusses with Pony Truss Approaches Pony Trusses with Timber Approaches Pony Trusses with Standard Precast Approaches Steel Beams with Timber Approaches Steel Beams with Standard Precast Approaches Regular Prestress with Standard Precast Approaches Special Steel with Steel Girder Approaches Deck Truss with Steel Girder Approaches |

In New Brunswick to address the quality of bridge inspections, the responsibility of inspecting all bridges between 3 and 6 meters in length was transferred from the District Bridge Maintenance personnel to the head office bridge inspectors in 2003. All bridges are now inspected by head office inspectors. This has resulted in a higher quality and more reliable reports. The Bridge Maintenance Engineer reviews the inspection reports and provides direct feedback to the inspectors on a weekly basis [34].

CHAPTER 5. MUNICIPAL BRIDGES

There are several hundred municipalities responsible for bridge management across Canada. Municipalities range from large, urban cities such as the cities of Toronto (with a population of 2,503,281 in the 2006 census [27]) and Montreal (with a population of 1,620,693 in the 2006 census [27]); through small, rural villages and towns; to remote hamlets in the north such as Pangnirtung, an Inuit hamlet, in the territory of Nunavut, located on Baffin Island (with a population of 1,325 in the 2006 census [28]). In the province of Ontario alone, there are over 440 municipalities responsible for bridge management [4].

Table 20 summarizes the number of municipalities and the different types of municipal structures for provinces and territories.

Because there are several hundred municipalities across Canada responsible for bridge management, it is difficult to get the required information from all municipalities. As a result, the standard questionnaire was not sent to the municipalities. Therefore, this paper cannot offer a comparison or statistical analysis for municipal bridges. It does, however, provide a number of challenges faced by municipalities and recommendations that will ensure a healthy future for municipal bridge infrastructure.

5.1. Challenges with Municipal Bridge Management

Through the literature review, municipal bridge management is first identified and then crosschecked with the responses of provincial agencies to the standard survey questionnaire. Table 3 shows the identified municipal bridge management challenges extracted from previous research studies, and Table 4 lists six important municipal bridge-management challenges determined by this study.

Table 20: Number of Municipalities and Types of Municipal Structures for Provinces and Territories

| Province/Territory | Number of Municipalities | Types of Municipal Government Structures |
|-----------------------|--------------------------|--|
| British Columbia | N.A. | 4 |
| Alberta | 41-60 | 4 |
| Saskatchewan | > 100 | 1 |
| Manitoba | > 100 | 5 |
| Ontario | > 100 | 3 |
| Quebec | 0-20 | 1 |
| New Brunswick | 0-20 | N.A. |
| Prince Edward Island | N.A. | N.A. |
| Nova Scotia | 0-20 | N.A. |
| Yukon Territory | 0-20 | 1 |
| Northwest Territories | 0-20 | 1 |

All the municipal bridge-management challenges are compiled into four groups: oversight, regulation, outreach, and miscellaneous. Table 6 lists all the challenges according to their groups. The six identified important municipal bridge-management challenges are discussed in detail in the following sections.

5.1.1.1. Downloading of Bridges

Due to downloading of bridges from provinces to municipalities, they are now the largest and most important bridge infrastructure owners. This fact is evident in Tables 1

and 21. Table 21 demonstrates roads (which include bridges) that have a very high municipal ownership component.

Table 21: Distribution of Roads Capital Assets 2005: Canada [5]

| | |
|------------|-----------------|
| Federal | 2.0% per annum |
| Provincial | 51.3% per annum |
| Municipal | 46.7% per annum |
| | 100% per annum |

In 1961, during the initial phase of heavy investment in Canada’s infrastructure, federal, provincial/territorial, and municipal governments each controlled 23.9%, 45.3%, and 30.9% of the national capital stock, respectively. By 2002, the federal government’s share had dropped from 23.9% to 6.8%, and the municipal share had grown from 30.9% to 52.4% of all infrastructures, an increase of nearly 70% [6].

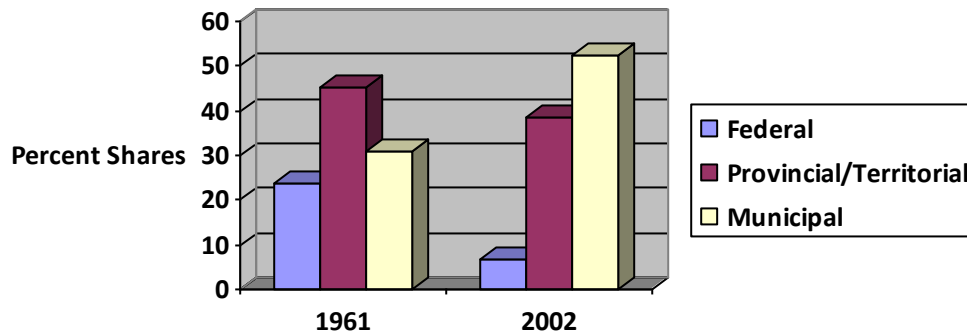


Figure 3: Public Capital Stock in Canada [6]

In Ontario in 1996/97 as part of the Local Services Realignment (LSR) strategy, there were numerous provincial highways deemed to serve more of a local function that were transferred to municipalities, and the bridges were transferred with them. Before that time and since that time, bridges are periodically transferred. That is if a highway is realigned, the old segment of roadway may be transferred to municipalities.

In 1993, the Quebec government transferred responsibility for provincial roads and bridges to municipalities. In the wake of the September 2006 de la Concorde overpass collapse, a commission of inquiry recommended that Quebec's Ministry of Transportation regain ownership of all bridges from municipalities with a population of 100,000 or less [7]. Steps should now be taken to safeguard municipal bridges across Canada. We should not be waiting for a disaster, i.e., catastrophic bridge collapse, and then a commission of inquiry recommending steps similar to the one above.

5.1.2. No Central Database and Comprehensive Inventory

At present, there is no central database and comprehensive bridge inventory of municipal bridges in the provinces of British Columbia, Manitoba, Ontario, Quebec, Nova Scotia, and Yukon Territory. This detail is shown in column 5 of Table 22. Bridge inventory is the core of any BMS. Without an accurate inventory, bridges cannot be effectively managed. The first step in developing an effective BMS is having an accurate bridge inventory.

This point is also echoed by the commission of inquiry (the “Johnson Commission”) about the collapse of a portion of the de la Concorde overpass; although the province of Quebec, like most provinces, maintains one or more databases about bridges and overpasses in its jurisdiction, the data maintained were not sufficient.

Table 22: Municipal Oversight Role # 1

| Province/Territory (1) | Does your Provincial ministry have any oversight role over the safety of bridges owned by other agencies in your Province/Territory (bridge belonging to municipalities and cities)? (2) | Does your Provincial/Territorial government provide grants and technical expertise to the municipal bridge owners for the inspection and maintenance of their bridges? (3) | Does your Provincial/Territorial government download bridges to municipalities? (4) | Is there any central database of bridges (all of the bridges, this includes bridges owned by municipalities, cities, etc) in your Province/Territory? (5) | Do other bridge owners in your Province/Territory such as cities and municipalities follow the same inspection frequency as you? (6) |
|---------------------------|--|---|--|---|---|
| British Columbia | No | No | Yes | No | N.A. |
| Alberta | Yes | No | Yes | Yes | Yes |
| Saskatchewan | No | Yes | No | Yes | Yes |
| Manitoba | No | Yes | No | No | No |
| Ontario | No | Yes | Yes | No | Yes |
| Quebec | No | No | No | No | No |
| New Brunswick | Yes | No | No | Yes | No |
| Prince Edward Islands | | | No | Yes | N.A. |
| Nova Scotia | No | No | No | No | No |
| Yukon Territory | No | No | No | No | Unknown |
| Northwest Territories | Yes | No | Yes | Yes | Yes |

The commission recommended that the Quebec transport department, as well as larger municipalities, implement an accelerated, comprehensive, and easily accessible on-line system that contains all records and data relevant to bridge and overpass structures in the province, including reports on inspections and repair activities [3].

Establishing a central comprehensive bridge inventory of all the bridges at the national or provincial level will not be a new or unique venture. There are existing examples of comprehensive bridge inventories which could be used as a model for a full inventory of municipal bridges.

One such example is the United States National Bridge Inventory (NBI). The NBI is a collection of information (a database) covering just under 600,000 of the U.S. bridges located on public roads, including interstate highways, U.S. highways, state and county roads, as well as publicly accessible bridges on federal lands. The NBI presents a state-by-state summary analysis of the number, location, and general condition of highway bridges within each state [29]. The data can be used to analyze bridges and to judge their condition. It provides a searchable and easily updatable database of bridge identification information; bridge types and specifications; operational conditions; and bridge data, including geometric data and functional description, inspection data, etc. [3].

After evaluation of the inspection data, the FHWA provides states with a list of bridges that are eligible for replacement or rehabilitation. The FHWA uses the data to submit a required biannual report to Congress about the status of the nation's bridges, to publish an Annual Materials Report on New Bridge Construction and Bridge Rehabilitation in the Federal Register, and to apportion funds for the Highway Bridge Program [29].

Collection of NBI data is authorized by statute, 23 U.S.C. 151 (National Bridge Inspection Program), and implemented by regulation, 23 CFR 650.301 et seq. In accord with these authorities, the FHWA established National Bridge Inspection Standards (NBIS) for the safety inspection and evaluation of highway bridges; each state is required to conduct periodic inspections of all bridges subject to the NBIS, to prepare and maintain a current inventory of these structures, and to report the data to the FHWA using the procedures and format outlined in the Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges [29].

Thus, NBIS is a federal regulation in the United States which establishes requirements for bridge-inspection procedures, frequency of inspections, qualifications of inspection personnel, inspection reports, and the preparation and maintenance of the NBI. The NBIS applies to all structures of 20 feet or more in length located on public roads [29].

The NBIS regulation came in 1971 after the tragic collapse of the Silver Bridge into the Ohio River, at Point Pleasant, West Virginia, on December 15, 1967; which killed 47 people. This tragic event aroused national interest in the U.S. in the safety inspection and maintenance of bridges [14].

Lessons should be learned. Canada does not have to wait for a bridge collapse, such as Silver Bridge, to establish a national or provincial-wide NBIS. In Canada, a model similar to NBIS could be adopted.

5.1.3. Lack of Funds and Expertise

According to Statistics Canada, “Governments (includes Federal and all 10 Provinces) have boosted the flow of investment in roads (including bridges) from \$4.3

billion in 1998 to \$7.3 billion in 2005, but this has barely offset the erosion of the road system.” However, the 2007 FCM-McGill survey indicates that municipalities need an additional \$21.7 billion to maintain and upgrade existing transportation infrastructure assets. The survey considered roads, sidewalks, bridges and curbs as part of the transportation infrastructure category [6].

Municipalities, especially small, rural municipalities, are facing enormous challenges to effectively manage their bridges because they do not have sufficient funds and expertise (e.g., bridge engineers and technologists). An important concern in this area lies with municipalities that do not have the resources or the tax base to fund the required rehabilitation. Due to funding pressures, these municipalities tend to act on a short-term basis and simply react to infrastructure rehabilitation needs. This situation only exacerbates the problem. Smaller municipalities typically do not have sufficient funds for emergency repairs. They may not have funds available to conduct preventive bridge rehabilitation or to undertake bridge inspections on a regular basis [5].

The Standing Committee on Public Accounts of the legislative assembly of Ontario, in its report on bridge inspection and maintenance, highlighted backlogs in bridge maintenance by dollar amount, expenditure, and years of backlog for four unnamed municipalities in Ontario. In one instance, there were 823 bridges rated in fair to poor condition with a 19.5-year backlog, totaling \$117.5 million in expenditures [7].

At present, the provinces of British Columbia, Alberta, Quebec, New Brunswick, Nova Scotia, Yukon Territory, and Northwest Territories do not provide grants and technical expertise to the municipal bridge owners for the inspection and maintenance of their bridges. This is evident in column 3 of Table 22.

Ontario has provided several grants and loans to municipalities over the past years, some in conjunction with the federal government. Jointly, these grants and loans include Canada-Ontario Municipal Rural Infrastructure Fund (COMRIF), Building Canada Fund-Communities Component (BCF-CC), and Infrastructure Stimulus Fund (ISF). Provincially, these grants and loans include the Municipal Infrastructure Investment Initiative (MIII), Invest in Ontario Fund, Move Ontario, Rural Infrastructure Investment Initiative (RIII), and Ontario Infrastructure Projects Corporation (OIPC). Typical funding is one-third federal, one-third provincial, and one-third municipal, although each funding initiative has different agreements.

5.1.4. Legislation for Bridge Inspection and Management

At present, Ontario is the only province where bridge inspections are a legislated requirement (province wide). This is evident in column 2 of Table 23. Ontario Regulation 104/97, part of the Public Transportation and Highway Improvement Act (PTHIA), states that all bridges must be inspected every 2 years under a professional engineer's direction using the ministry's Ontario Structure Inspection Manual (OSIM). The manual requires a "close-up" inspection which involves visual assessments of each bridge element as well as its material defects, performance deficiencies, and maintenance and rehabilitation needs. Under provincial legislation, all bridge owners are required to conduct biennial inspections using the OSIM as the basis for that inspection. All owners, whether a municipality, a railway, or a private firm, must, by law, complete these inspections [7]. However, there is currently no legislation that requires or even enables the Ministry of Transportation (MTO) or any other ministry to oversee municipalities' compliance with this requirement.

There should be a federal or provincial legislation concerning the safety of bridges. It should be for all bridges regardless of the ownership. All responsibilities, tasks, and duties should be clearly and unambiguously defined. There should not be any doubt about who is responsible for what. Again, the NBIS of the United States can be used as a model.

5.1.5. Provincial Oversight Role

Municipalities, especially small, rural ones, need someone who has expertise, experience, and resources, such as a provincial ministry of transportation, to provide the leadership and support in terms of the oversight, standards, expertise, and funding. There is no oversight role by most of the provinces to ensure that bridges are being effectively managed, that inspections are performed consistently, and that measures are taken when municipal owners identify deficiencies.

As mentioned in Section 5.1.4, Ontario is the only province which has regulations about the inspection and maintenance of bridges. Municipal bridges are subject to the same high standards as provincial bridges. However, there is no single body responsible for bridge oversight, such as monitoring municipal compliance with legislated inspection and maintenance requirements. The Standing Committee on Public Accounts of the legislative assembly of Ontario stated in its report on bridge inspection and maintenance that “without a strong central body to oversee municipal bridge inspections, public reporting, and the judicious application of penalties where appropriate, the Committee fears that some municipalities may not be fulfilling their obligations to inspect and maintain their bridge infrastructure” [7]. Due to the National Bridge Inspection Standards

Table 23: Municipal Oversight Role # 2

| Province/Territory (1) | Are there any laws or regulations related to inspection of bridges in your Province/Territory? (2) | Is there any Provincial/Territorial regulation for bridge inspection and maintenance in your Province/Territory? (3) | Who is responsible for inspection of bridges belonging to cities, towns, counties, municipalities, villages, districts, etc. in your Province/Territory? (4) | If this is the responsibility of the owner of the bridge (i.e., municipalities and cities), is there any involvement of your Provincial/Territorial ministry to make sure the inspection is carried out? (5) | Is your Provincial/Territorial ministry responsible or has any role in ensuring that the municipal bridge inspections and maintenance work is carried out effectively by the municipal owners? (6) |
|------------------------|--|--|--|--|--|
| British Columbia | No | No | The owner of the bridge | No | No |
| Alberta | No | No | The Province & The owner of the bridge | Yes | Yes |
| Saskatchewan | No | No | The owner of the bridge | No | No |
| Manitoba | Yes | No | The owner of the bridge | No | No |
| Ontario | Yes | Yes | The owner of the bridge | No | No |
| Quebec | No | No | The Province & The owner of the bridge | No | No |
| New Brunswick | No | No | The owner of the bridge | Yes | Yes |
| Prince Edward Island | No | No | The Province | | |
| Nova Scotia | Yes | No | The owner of the bridge | No | No |
| Yukon Territory | No | No | The owner of the bridge | No | No |
| Northwest Territories | No | No | The Province | | Yes |

(NBIS), each state in the USA must maintain an oversight role for the safety of its bridges.

At present, Alberta, New Brunswick, and Northwest Territories have oversight role over the safety of bridges owned by municipalities. This is shown in column 7 of the Table 14. Prince Edwards Island and Northwest Territories do inspection of all public owned bridges regardless of ownership.

5.1.6. Lack of a Municipal Bridge-Management System across Provinces/Territories

As shown in Table 24, column 2, municipalities do not use provincial/territorial BMS system. There are several hundred municipalities across Canada (in Ontario alone, there are 444 municipalities [5].) responsible for bridge management, yet they all use different BMSs to manage their bridges. Some have more sophisticated ones; others have a database; and some have nothing.

Thus, a precise picture about the overall condition of municipal bridges as well as accurate comparisons between municipal and provincial bridges is difficult because municipalities use many different systems to classify and determine the condition of their bridges. Further, there is no central database for the number of municipal bridges and their overall conditions [7].

One possible solution for the above problem is to have a dedicated municipal BMS. The Municipal Data Works (MDW) currently used in many municipalities in Ontario could be the answer. The MDW is a web-based infrastructure asset repository system owned and managed by the Ontario Good Roads Association (OGRA) with startup funding provided by the Ontario Ministry of Transportation (MTO) [7]. OGRA represents the infrastructure interests of 432 of Ontario's 444 municipalities [30]. MDW

supports over 120 unique asset types, including roads and bridges. MDW was developed under a public-private partnership with the goal of providing asset-management capabilities to even the smallest municipalities [7].

On March 24, 2010, the OGRA and MTO entered into an agreement to support municipal bridge infrastructure. The Ontario government will provide \$750,000 to help Ontario municipalities collect and report data about the extent and condition of bridge structures in their jurisdictions. All municipalities will be able to apply for matching funds to a maximum of \$5,000 to assist them with the costs of collecting, collating, compiling, formatting, and inputting bridge asset and condition data into MDW.

By December 2009, of the 444 Ontario municipalities, 289 have committed to sharing information on municipal bridge inspection and maintenance through MDW. That number represents over 65% of Ontario municipalities, and through the use of new tools that will be built, OGRA hopes to have bridge data on the majority of structures in the province in a central database and will share that information with the province [31]. Similar exercises could be taken in other provinces.

The bridge inspection module of MDW is based on the OSIM. OSIM is an element-by-element inspection of a bridge. MDW uses the inputs from the element-by-element inspection to calculate a Bridge Condition Index (BCI) and Bridge Sufficiency Index (BSI). The bridge inspection module of MDW is as follows [32]:

- It is flexible and will allow the structural engineer to adopt as little or as much OSIM detail as he/she requires.

- Easy to use: once the original element groups and elements are identified, subsequent inspections are automatically populated with the original element groups and elements.
- The module does all the work to calculate the Bridge Condition Index (BCI) value.
- The inspection output is stored in MDW as a life-cycle event for that bridge.
- The inspection detail is retained until it is deleted by the user.

As mentioned in Section 4.6.3, the OSIM is being used in five other provinces (Saskatchewan, Manitoba, New Brunswick, Prince Edward Island, and Nova Scotia) to conduct bridge inspection. MDW is based on OSIM, thus it can easily be implemented at least in the above-mentioned provinces to help municipalities effectively manage their bridges.

Table 24: Municipal Oversight Role # 3

| Province/Territory (1) | Do other jurisdictions in your Province/Territory (such as cities, towns, counties, municipalities, villages, districts, etc) use your BMS system or they have their own? (2) | Are these requirements (i.e. educational and physical qualifications of inspectors) used throughout the Province i.e. by municipal bridge owners or they have their own requirements? (3) | Is there any training for inspectors working for municipalities and cities by the Provincial/Territorial government? (4) | Do you have Provincial/Territorial standards, procedures, manuals, guidelines, etc. for inspection and condition ratings Provincial/Territorial wide or each jurisdiction within your Province/Territory has its own? (5) | What role does your Provincial/Territorial ministry play in the process of ensuring quality and safety of bridges of other jurisdictions, such as cities, municipalities, etc? (6) |
|------------------------|---|---|---|---|--|
| British Columbia | Does not use Ministry's BMS. No information about what other jurisdictions use. | No | Not directly although Ministry's self-directed bridge-inspection courses are available thru the BC Institute of Technology. | Each jurisdiction in the province has its own | No role |
| Alberta | Other jurisdictions have their own | Yes | Yes | Same throughout the province | Some role |
| Saskatchewan | Do not know | No | No | Each jurisdiction in the province has its own | No role |
| Manitoba | N.A. | No | N.A. | Each jurisdiction in the province has its own | No role |
| Ontario | Varies: about 10 municipalities use an earlier version of OBMS; some use MDW; some have their own system. Exact numbers are not known. | No | No | Same throughout the province | No role |
| Quebec | Other jurisdictions have their own | No | No | Each jurisdiction in the province has its own | No role |
| New Brunswick | Other jurisdictions have their own | No | No | Same throughout the province | Full role |
| Prince Edward Islands | N.A. | N.A. | N.A. | Same throughout the province | Full role |
| Nova Scotia | Other jurisdictions have their own | No | | Each jurisdiction in the province has its own | No role |
| Yukon Territory | Unknown | Unknown | No | Same throughout the province | No role, unless invited |
| Northwest Territories | Will be managed by territorial government once it has BMS in place | | No | Same throughout the province | Full role |

CHAPTER 6. SUMMARY AND RECOMMENDATIONS

6.1. Summary

Bridges are very important elements of horizontal transportation systems. Due care must be given to them because they are ageing and because a bridge collapse could result in considerable loss of life, property, environment, and economy. Increased traffic volume and heavier loads are adding additional strain on them. Thus, the importance of effective bridge-management practices cannot be overemphasized.

This paper reviewed and documented bridge inspection and maintenance practices of provincial/territorial ministries of transportation. The standard survey questionnaire was sent to all federal and provincial/territorial transportation agencies responsible for bridge management. Nine of ten provincial, three of three territorial, and two of nine federal agencies responded to the survey. Responses are summarized in 17 tables in this paper. Because most of the provincial agencies responded their bridge management practices are comprehensively analyzed and documented.

Based on the literature review and an evaluation of the survey data, provincial/territorial transportation agencies are providing effective bridge management. These tiers of government have the resources, experience, and expertise to perform the tasks required. Currently four provinces have computerized BMS. The remainder of the provinces and territories are in the process of acquiring a computerized BMS. The Ontario Structure Inspection Manual (OSIM), developed by province of Ontario, is the most widely used bridge inspection system in Canada. At present, five provinces employ this system to conduct bridge inspections. Most provinces/territories have certification

programs for bridge inspectors with the exception of Manitoba, Ontario, and the Northwest Territories.

This study determined a total of six important municipal bridge-management challenges and recommendations that will ensure a healthy future for municipal bridge infrastructure. The six challenges are: downloading (giving away) bridges from provinces to municipalities; no central database and comprehensive bridge inventory; lack of funds and expertise; legislation for bridge inspection and management; provincial oversight role; variable or no Municipal Bridge Management System across provinces/territories. Years of downloading bridges from provinces to municipalities have increased their bridge inventory. In fact, they are now the largest and most important bridge infrastructure owners. In 1961, during the initial phase of heavy investment in Canada's infrastructure, federal, provincial/territorial, and municipal governments each controlled 23.9%, 45.3%, and 30.9% of the national capital stock, respectively. By 2002, the federal government's share had dropped from 23.9% to 6.8%, and the municipal share had grown from 30.9% to 52.4% of all infrastructures, an increase of nearly 70% [6]. Similarly in the 1990s province of Ontario and Quebec also transferred bridge ownership to the municipalities. There is no central database and comprehensive bridge inventory in most of the provinces. Ontario is the only province where bridge inspections are a legislated requirement (province wide) for all public bridges regardless of the ownership. Municipalities use many different systems to classify and determine the condition of their bridges. Municipalities (especially the small, rural ones) need a provincial or federal body to provide leadership and support in terms of the oversight, standards, expertise, and funding. One right step in this direction is a

partnership between Ontario's Ministry of Transportation (MTO) and the Ontario Good Roads Association (OGRA), which represents the infrastructure interests of 432 of Ontario's 444 municipalities to support municipal bridge infrastructure. The Ontario government will provide \$750,000 to help Ontario municipalities collect and report data about the extent and condition of bridge structures in their jurisdiction. This funding is to assist municipalities with the costs of collecting, compiling, formatting, and inputting bridge asset and condition data into Municipal Data Works (MDW). The MDW is a web-based infrastructure asset repository system owned and managed by the OGRA. The bridge inspection module of MDW is based on the Ontario Structure Inspection Manual (OSIM) [5]. OSIM is being used in five other provinces (Saskatchewan, Manitoba, New Brunswick, Prince Edward Island, and Nova Scotia) to carry out bridge inspection. Because MDW is based on OSIM, it can easily be implemented, at least in the above-mentioned provinces, in helping municipalities to effectively manage their bridges. Similar initiations should be taken in other provinces.

6.2. Recommendations

As demonstrated in Table 22, 23, and 24 that there is no single agency or government body that has all the information for the state of the municipal bridges in most of the provinces. Moreover, there is no one agency responsible for ensuring that bridge inspections and rehabilitation work are done. There should be a federal or provincial legislation (regulation) concerning the safety of bridges. It should be for all public bridges, regardless of the ownership, similar to the U.S. Department of Transportation's Federal Highway Administration (FHWA) National Bridge Inspection Standards (NBIS). Thus, it is recommended that a working group should study NBIS and

other systems in the world, and then, a new system should be developed and tailored to fit the Canadian need. In the proposed regulation, all responsibilities, tasks, and duties should be defined clearly and unambiguously. There should not be any doubt about who is responsible for what. A provincial or federal agency should be responsible to ensure that municipalities are inspecting bridges in accordance with the proposed regulation and that the bridges are safe for public use. Figure 4 depicts the strategy for the proposed Canadian bridge inspection standards.

The main objectives of this paper were to obtain and document bridge inspection and maintenance practices of federal and provincial/territorial ministries of transportation and to document challenges currently faced by Canadian municipalities while managing their bridges. Both the objectives are met. To achieve the first objective structured questionnaires were sent to all provincial, territorial, and federal transportation ministries responsible for bridge management in Canada. Responses to the standard questionnaire were obtained from nine provincial, three territorial, and two federal transportation agencies. Responses from the provincial/territorial transportation ministries are summarized in 11 tables in Chapter 5: Provincial/Territorial Bridges, which forms a database of their bridge inspection and maintenance practices. Only two federal agencies responded to the survey, and these agencies only manage nine bridges. As a result, federal agencies' bridge-management practices were not documented. The six important municipal bridge-management challenges determined by this paper are listed in Table 4 in Chapter 2. Literature Review and all six challenges are discussed in detail in Chapter 5. Municipal Bridges.

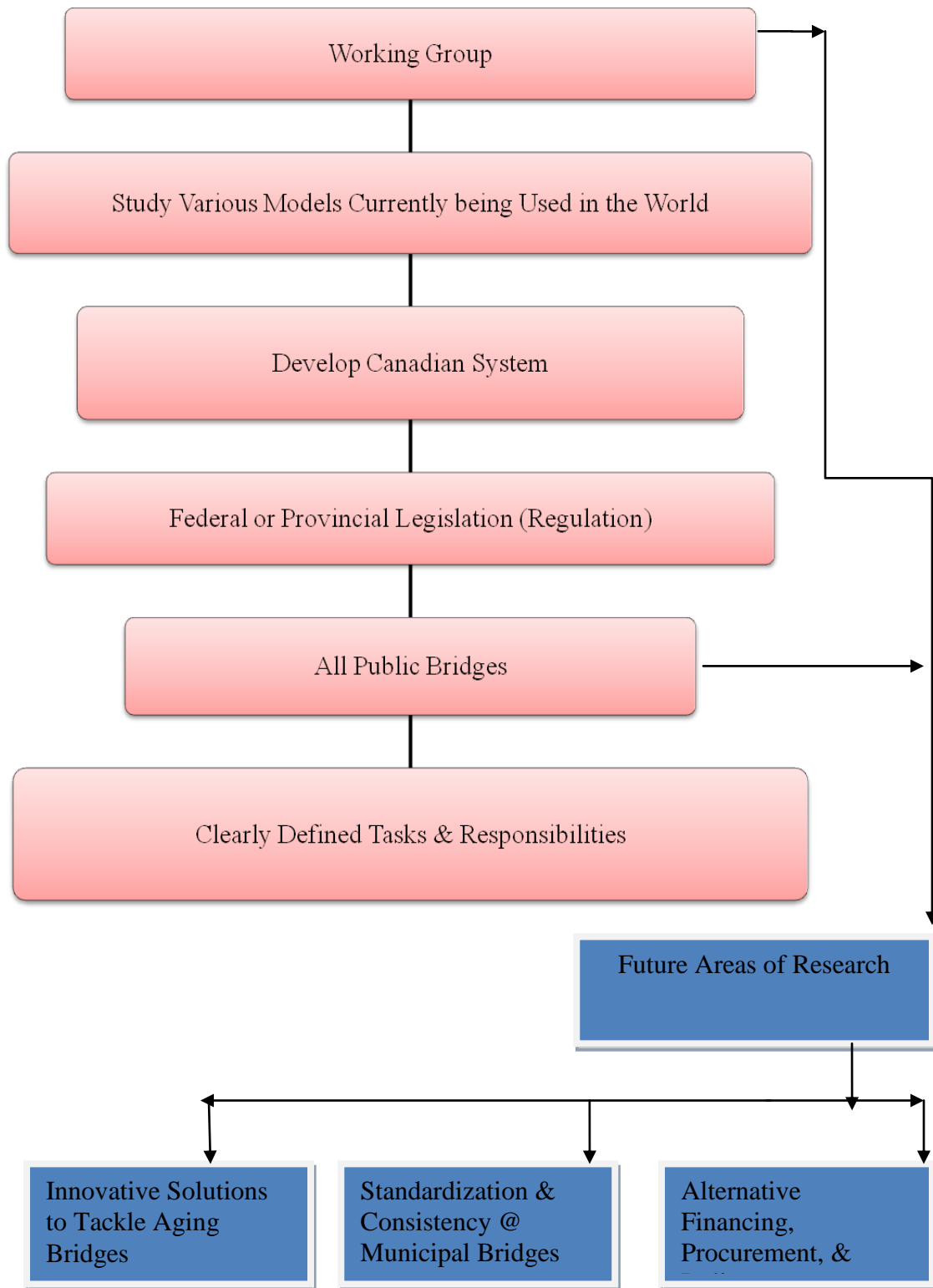


Figure 4: Flow Chart Showing Strategy for Proposed Canadian Bridge Inspection Standards

6.3. Research Contributions

This paper makes following contributions:

1. **Bridge Inventory:** This paper demonstrated distribution of the number of bridges managed by three levels of government arranged by provinces/territories. As shown in the Table 1, there are about 75,000 bridges. At present, there is no central database and comprehensive bridge inventory of municipal bridges in the provinces of British Columbia, Manitoba, Ontario, Quebec, Nova Scotia, and Yukon Territory. This detail is shown in column 5 of Table 22. Bridge inventory is the core of any BMS. Without an accurate inventory, bridges cannot be effectively managed. The first step in developing an effective BMS is having an accurate bridge inventory.
2. **Aging Bridge Infrastructure:** As shown in Table 2, the majority of provincial bridges are between or over 26-50 years old. Nova Scotia has the most (50%) bridges over 51 years old, followed by Federal Bridge Corporation Limited (43%), Quebec (31.2%), Yukon Territory (25%), Ontario and Saskatchewan (19%), New Brunswick and Manitoba (18%), Prince Edward Island (16%), British Columbia (13%), and Blue Water Bridge Canada (1%). Depending on the type of bridge, construction methodology, and degree of maintenance, it is expected that most bridges will require costly rehabilitation or replacement after 50 years of service life.

3. Bridge Management System (BMS): As shown in Table 8, Saskatchewan, Manitoba, New Brunswick, Nova Scotia, Yukon Territory, and the Northwest Territories do not have a computerized BMS. Alberta has the oldest system while Prince Edward Islands has the newest system.
4. Bridge Inspection Manual: As shown in Table 10, there are four different types of manuals that document bridge-inspection processes: British Columbia's Bridge Inspection Manuals, Books 1, 2, and 3, dated 1994; Alberta's Bridge Inspection and Maintenance (BIM) Manual Version 3.0, dated 2005; Quebec's Manuel d'inspection des structures – Instruction techniques; and Ontario's Ontario Structure Inspection Manual (OSIM). OSIM is the most used inspection manual in the country. Six provinces (Saskatchewan, Manitoba, Ontario, New Brunswick, Prince Edward Islands, and Nova Scotia) are undertaking their bridge inspections based on this manual. Alberta's Bridge Inspection and Maintenance (BIM) manual is currently being used by Yukon Territory and the Northwest Territories.
5. Personnel Qualifications: As shown in Table 16, Manitoba and the Northwest Territories do not have certification programs for their bridge inspectors. Ontario has an inspection-training program that is required for inspectors, who do work for the ministry. It can be said that Ontario does not have a certification program. Provinces that offer certification programs certify the inspectors themselves, except in Nova Scotia. The U.S. Department of Transportation Federal Highway Administration

(FHWA) certifies inspectors in Nova Scotia. In provinces that have certification programs, only British Columbia, Saskatchewan, and the Yukon Territory do not have re-certification requirements. All the provinces and territories have educational and physical qualifications requirements for inspectors.

6. Structural Health Monitoring (SHM): As shown in Table 17, only Quebec and New Brunswick employ structural health monitoring (SHM) as a bridge-management tool.
7. Documentation: As shown in the Table 18, Alberta has the most (25) standard inspection forms. In all provinces and territories, a bridge engineer reviews the inspection reports. In Ontario detailed visual inspections must be performed under the direction of a professional engineer. The head office inspect about 50 bridges a year and compare the results to regional inspection results (both in-house and consultant).
8. Legislation: As shown in column 2 of Table 23, Ontario is the only province where bridge inspections are a legislated requirement (province wide). Ontario Regulation 104/97, part of the Public Transportation and Highway Improvement Act (PTHIA), states that all bridges must be inspected every 2 years under a professional engineer's direction using the ministry's Ontario Structure Inspection Manual (OSIM). However, there is currently no legislation that requires or even enables the Ministry of Transportation (MTO) or any other ministry to oversee municipalities' compliance with this requirement.

9. Municipal Bridge-Management Challenges: As shown in the Table 4, this paper identified six municipal bridge-management challenges. Challenges were refined based upon importance, severity, and relevance.

6.4. Future Areas of Research

In spite of the potentials and benefits of this paper, it has limitations that could be improved through further research:

1. Canadian bridge infrastructure is aging. It is crucial to develop a clear and well-defined policy possibly at the federal level to address the looming problem. Research should be conducted to find innovative solutions to extend bridge service life not only for the existing bridges but also for the new construction.
2. More focused research is needed to bring standardization and consistency in municipal bridge management.
3. Research is needed in the area of alternative financing, procurement, and delivery to minimize short and long-term bridge rehabilitation, construction, and maintenance costs.

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APPENDIX A. PROVINCIAL STANDARD SURVEY QUESTIONNAIRE

State of Bridge Management in Canada Survey Questionnaire

General Information:

Respondent's Name: _____

Position/Title: _____

Company Name: _____

Address: _____ City: _____ Province: _____ Postal Code: _____

Phone No.: _____ Fax. No.: _____ Email: _____

Topic # 1: Organizational Structure and Background:

1. Who owns roadway bridges in your Province/Territory?

Province Cities Municipalities Others (please specify)

2. Who owns railway bridges in your Province/Territory?

Railway Companies Province Cities Municipalities Others (please specify)

3. Who is responsible for inspection and maintenance of roadway bridges in your Province/Territory?

Province Cities Municipalities Bridge Owner Others (please specify)

4. Who is responsible for inspection and maintenance of railway bridges in your Province/Territory?

Railway Companies Province Cities Municipalities Others (please specify)

5. Are there any laws or regulations related to inspection of bridges in your Province/Territory?

No Yes. If yes, please specify laws.....

6. Is there any Provincial/Territorial regulation for bridge inspection and maintenance in your Province/Territory?
- No Yes. If yes, please specify laws.....
7. Who is responsible for inspection of bridges belonging to cities, towns, counties, municipalities, villages, districts, etc. in your Provincial/Territorial?
- The Province/Territory The owner of the bridge
8. If this is the responsibility of the owner of the bridge (i.e. municipalities and cities), is there any involvement of your Provincial/Territorial ministry to make sure the inspection is carried out.
- Yes No Other (please specify)
9. Is your Provincial/Territorial ministry responsible or has any role in ensuring that the municipal bridge inspections and maintenance work is carried out effectively by the municipal owners?
- Yes No Other (please specify)
10. Does your Provincial ministry have any oversight role over the safety of bridges owned by other agencies in your Province/Territory (bridge belonging to municipalities and cities)?
- YesNo If yes, to what extend (please specify)
11. Does your Provincial/Territorial government provide grants and technical expertise to the municipal bridge owners for the inspection and maintenance of their bridges?
- Yes No If yes, to what extend (please specify)
12. Does your Provincial/Territorial government download bridges to municipalities?
- Yes No If yes, to what extend (please specify)
13. How many municipalities (i.e. number of municipalities) are responsible for bridge inspection and maintenance in your Province/Territory?
- 0-20 21-40 41-60 61-80 81-100 Greater than 100

14. How many different types of municipal government structures (i.e. regions, counties and single-tier municipalities, etc) are there in your province that are responsible for bridge inspection and maintenance.

1 2 3 4 5 Greater than 5

15. Who is responsible for maintaining inventory of bridges in your Province/Territory?

Province The owner of the bridge Others (please specify)

16. What is the total numbers of bridges are in your Province/Territory (both roadway and railway including bridges owned by other agencies i.e. municipalities, cities, etc)?

Roadway bridges.....

Railway bridges.....

17. Is there any central database of bridges (all of the bridges, this includes bridges owned by municipalities, cities, etc) in your Province/Territory?

Yes No Others (please specify)

18. How old are your bridges. What percentage of bridges are:

Less than 25 Years - % ____ 25-50 Years - % ____ 51-75 Years - %

76-100 Years - % ____ Greater than 100 Years old - %

19. What is the average age of your Province's bridge infrastructure?

Less than 25 Years 26-50 Years 51-75 Years 76-100 Years Other (please specify)

Topic # 2: Inspection Data:

1. What different types of inspections are performed on bridges?:

Initial Cursory Visual Routine Detail Underwater
Other (please specify)

2. Do you perform hands-on/close-up inspection? This is physically touching and sounding each and every elements of a bridge. This may require lane closure and use of an under-bridge inspection vehicle.
- Yes No
3. What is the frequency of bridge inspection in your Province/Territory?
- Biannually Annually Every Two Years Every Three Years
- Every Four Years Every Five Years Other (please specify)_____
4. Do other bridge owners in your Province/Territory such as cities and municipalities follow the same inspection frequency as you?
- Yes No Other (please specify)
5. What requirements exist (if any) for special inspections (such as after a severe flood, earthquake, etc)?
6. What are the data used for? Are the inspection data integrated into a bridge management system for managing a maintenance, rehabilitation, and replacement program?
- Yes No
7. Do you have a computerized Bridge Management System (BMS)?
- Yes No If yes, which one is it (please specify).
8. If yes, when did you start using a computerized BMS?
9. If no, what system are you using? How are you managing your bridges?
10. Is your system fully developed or under development?
- Fully Developed Under Development Other (please specify)
11. Do other jurisdictions in your Province/Territory (such as cities, towns, counties, municipalities, villages, districts, etc) use your BMS system or they have their own?
- Use Province's They have their own Other (please specify)

12. What is your bridge inspection condition rating scale?

- 0(failed)-9(excellent) 0(Failed)-7(excellent)
Failed, Very Poor, Poor, Fair, Very Fair, Good, Very Good, Excellent
Other (please identify)_____

Topic # 3: Personnel Qualifications:

1. Are bridge inspectors formally certified?

- Yes No Other (please specify)

2. If yes, who certified them?

- Province Other (please specify)

3. Are educational and physical qualifications required of inspectors?

- Yes No If yes, what are the requirements (please specify)

4. Are there any re-qualification and re-certification requirements?

- Yes No Other (please specify)

5. Who sets these requirements?

- Province Other (please specify)

6. Are these requirements used throughout the Province i.e. by municipal bridge owners or they have their own requirements?

- Yes No Other (please specify)

7. How often are the inspectors trained?

- Semi-annually Annually Every 2 Years Every 5 Years
 Other (please specify)

8. Who trains them?

- Province Other (please specify)

9. Is there any training for inspectors working for municipalities and cities by the Provincial/Territorial government?

Yes No Other (please specify)

Topic # 4: Process Control:

1. Do you have Provincial/Territorial standards, procedures, manuals, guidelines, etc. for inspection and condition ratings Provincial/Territorial wide or each jurisdiction within your Province/Territory has its own?

Same throughout the province Each jurisdiction in the province has its own

2. What role does your Provincial/Territorial ministry play in the process of ensuring quality and safety of bridges of other jurisdictions, such as cities, municipalities, etc?

Full role Some role No role Other, please specify

Topic # 5: Equipment:

1. Is any nondestructive evaluation, nondestructive testing, or other advanced testing equipment used during bridge inspection?

No
 Yes and please specify type of equipment used.....

2. What remote monitoring technologies (if any) are being used to monitor bridges?

Scour Monitoring Strain Gauges Tilt Sensors Accelerometer
 Other, please specify

3. Do you use structural health monitoring (SHM) as a Bridge Management Tool?

Yes No

Topic # 6: Documentation:

1. Do standard inspection forms and report formats exist?

Yes No

2. If yes, how many different types?

3. What is the process of distribution, review and evaluation of inspection reports?

.....
.....

4. Who reviews the inspection reports?

Bridge Engineer Other Inspector Other, please specify

5. How long are inspection records kept?

1-5 Years 6-10 Years 11-15 Years 15-20 Years
 Life of the Bridge

Forever Other, please specify

Topic # 7: General Comments

1. Would you like to see a federal regulation in Canada similar to the National Bridge Inspection Standards (NBIS) of the United States Department of Transportation - Federal Highway Administration (FHWA)?

Yes No

2. Are you satisfied with the bridge management of other jurisdictions (such as municipalities, cities, towns, etc.) within your Province/Territory?

Fully Satisfied Partially Satisfied Not Satisfied
 Other, please specify

3. If not, how could (do you think) the system can be improved? -----

APPENDIX B. FEDERAL STANDARD SURVEY QUESTIONNAIRE

State of Bridge Management in Canada Survey Questionnaire

General Information:

Respondent's Name: _____

Position/Title: _____

Company Name: _____

Address: _____ City: _____ Province: _____ Postal Code: _____

Phone No.: _____ Fax. No.: _____ Email: _____

Topic # 1: Organizational Structure and Background:

20. Does your agency own a bridge?

No Yes If yes, how many? _____

21. Does your agency responsible for management of bridges?

No Yes If yes, how many? _____

22. How many different federal agencies are responsible for management of bridges?
Please provide names.

23. Who is responsible for inspection and maintenance of your agency's bridges?

My Agency Bridge Owner (please specify) Others (please specify)

24. Who is responsible for maintaining inventory of your agency's bridges?

My Agency Bridge Owner (please specify) Others (please specify)

25. Is there any central database of bridges (i.e. all of the bridges, this includes bridges owned by other federal agencies, provinces, municipalities, cities, etc)?

Yes No Others (please specify)

26. How old are your bridges. What percentage of bridges are:
- Less than 25 Years - % ____ 25-50 Years - % ____ 51-75 Years - ____%
- 76-100 Years - % ____ Greater than 100 Years old - ____%
27. What is the average age of your bridge infrastructure?
- Less than 25 Years 26-50 Years 51-75 Years
- 76-100 Years Other (please specify)
28. Is there any federal regulation for bridge inspection and maintenance?
- No
- Yes. If yes, please specify laws.....
29. Who is responsible for inspection of bridges belonging to other federal agencies, provinces, territories, cities, towns, counties, municipalities, villages, districts, etc.?
- Federal Government Province/Territory Bridge Owner
- Other (please specify)
30. If this is the responsibility of the owner of the bridge (i.e. other federal agencies, provinces, municipalities, cities, etc.), is there any involvement of your agency to make sure the inspection is carried out.
- Yes No Other (please specify)
31. Does your agency have any oversight role over the safety of bridges owned by other agencies (bridge belonging to other federal agencies, provinces, municipalities, cities, etc.)?
- Yes No If yes, to what extend (please specify)
32. Does your agency provide grants and technical expertise to other federal agencies, provincial and municipal bridge owners for the inspection and maintenance of their bridges?
- Yes No If yes, to what extend (please specify)
33. Does your agency download bridges to other federal agencies, provinces, municipalities, etc.?
- Yes No If yes, to what extend (please specify)

Topic # 2: Inspection Data:

13. What different types of inspections are performed on your bridges?
Initial Cursory Visual Routine Detail Underwater
Other (please specify)
14. Do you perform hands-on/close-up inspection? This is physically touching and sounding each and every elements of a bridge. This may require lane closure and use of an under-bridge inspection vehicle.
No Yes if yes, what is the frequency? _____
15. What is the frequency of bridge inspection?
Biannually Annually Every Two Years Every Three Years
Every Four Years Every Five Years Other (please specify)_____
16. Do other bridge owners such as other federal agencies, provinces, cities and municipalities follow the same inspection frequency as you?
Yes No Other (please specify)
17. What requirements exist (if any) for special inspections (such as after a severe flood, earthquake, etc)?
18. What are the data used for? Are the inspection data integrated into a bridge management system for managing a maintenance, rehabilitation, and replacement program?
Yes No Other (please specify)
19. Do you have a computerized Bridge Management System (BMS)?
Yes No If yes, which one is it (please specify).
20. If yes, when did you start using a computerized BMS?
21. If no, what system are you using? How are you managing your bridges?
22. Is your system fully developed or under development?
Fully Developed Under Development Other (please specify)

23. Do other jurisdictions such as other federal agencies, provinces, cities, towns, counties, municipalities, villages, districts, etc) use your BMS system or they have their own?

Use Ours They have their own Other (please specify)

24. What is your bridge inspection condition rating scale?

0(failed)-9(excellent) 0(Failed)-7(excellent)
 Failed, Very Poor, Poor, Fair, Very Fair, Good, Very Good, Excellent
 Other (please identify)_____

Topic # 3: Personnel Qualifications:

10. Are bridge inspectors formally certified?

Yes No Other (please specify)

11. If yes, who certified them?

My Agency Other (please specify)

12. Are educational and physical qualifications required of inspectors?

Yes No If yes, what are the requirements (please specify)

13. Are there any re-qualification and re-certification requirements?

Yes No Other (please specify)

14. Who sets these requirements?

Your Agency Other (please specify)

15. Are these requirements used throughout the federal agencies?

Yes No Other (please specify)

16. How often are the inspectors trained?

Semi-annually Annually Every 2 Years Every 5 Years
 Other (please specify)

17. Who trains them?

Your Agency Other (please specify)

18. Is there any training for inspectors working for other federal agencies, provinces, municipalities and cities by your agency?

Yes No Other (please specify)

Topic # 4: Process Control:

3. Do you have one federal standards, procedures, manuals, guidelines, etc. for inspection and condition ratings or each federal agency has its own?

Same throughout federal agencies Each federal agency has its own

4. What role does your agency play in the process of ensuring quality and safety of bridges of other jurisdictions, such as other federal agencies, provinces, cities, municipalities, etc?

Full role Some role No role Other, please specify

Topic # 5: Equipment:

4. Is any nondestructive evaluation, nondestructive testing, or other advanced testing equipment used during bridge inspection?

No
 Yes and please specify type of equipment used.....

5. What remote monitoring technologies (if any) are being used to monitor bridges?

Scour Monitoring Strain Gauges Tilt Sensors Accelerometer
 Other, please specify

6. Do you use structural health monitoring (SHM) as a Bridge Management Tool?

Yes No

Topic # 6: Documentation:

6. Do standard inspection forms and report formats exist?

Yes No

7. If yes, how many different types?

8. What is the process of distribution, review and evaluation of inspection reports?

.....
.....

9. Who reviews the inspection reports?

Bridge Engineer Other Inspector Other, please specify

10. How long are inspection records kept?

1-5 Years 6-10 Years 11-15 Years 15-20 Years

Life of the Bridge Forever Other, please specify

Topic # 7: General Comments

4. Would you like to see a federal regulation in Canada similar to the National Bridge Inspection Standards (NBIS) of the United States Department of Transportation - Federal Highway Administration (FHWA)?

Yes No

5. Are you satisfied with the bridge management of other jurisdictions (such as other federal agencies, provinces, municipalities, cities, towns, etc.)?

Fully Satisfied Partially Satisfied Not Satisfied Other, please specify

6. If not, how could (do you think) the system can be improved? -----

APPENDIX C. INFORMED CONSENT

NDSU

North Dakota State University

Department of Construction Management & Engineering
CME Building, Room 120
Fargo, ND 58105

NDSU Dept. 2475
PO Box 6050
Fargo, ND 58108-6050
701.231.7246

Title of Research Study: State of Bridge Management in Canada

Dear _____:

My name is Kamran Khanzada. I am a graduate student in the department of Construction Management & Engineering at North Dakota State University. I am conducting a research project to find out the state of bridge management in Canada. The research paper will focus on bridge inspection and maintenance practices of various agencies and organizations. This includes inspection types (scope, methods, and frequency), application of innovative technologies (sensors, warning systems, and others), inspection personnel (qualifications, training and certification, and inspection teams), and inspection quality control and quality assurance. In the end the paper will conclude with the recommendations to improve bridge management practices in Canada. It is our hope, that with this research, we will learn more about bridge management in Canada.

Because you are an official of the ministry of transportation and directly related to the management of bridges, you are invited to take part in this research project. Your participation is entirely your choice, and you may change your mind or quit participating at any time, with no penalty to you.

It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known risks. By taking part in this research, you may benefit by knowing the state of bridge management in other jurisdictions within Canada. Benefits to others are likely to include advancement of knowledge.

It should take about 40 minutes to complete the questions. Please respond in the text field provided by checking the appropriate box and return the survey to me by e-mail at kamran.khanzada@ndsu.edu. Please note submitting surveys via email may hold risks to participants' privacy and confidentiality, as email communications are not secure and some employers monitor use of email accounts. You will receive no compensation to participate in this research.

We will keep private all research records that identify you, to the extent allowed by law. Your information will be combined with information from other people taking part in the study, we will write about the combined information that we have gathered. You will not be identified in these written materials. We may publish the results of the study; however, we will keep your name and other identifying information private.

If you have any questions about this project, please call me at 613-612-9388 or e-mail kamran.khanzada@ndsu.edu, or call my advisor Dr. Eric Asa at 701.231.7246 or e-mail eric.asa@ndsu.edu.

You have rights as a research participant. If you have questions about your rights or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program at 701.231.8908, ndsu.irb@ndsu.edu, or by mail at: NDSU HRPP Office, NDSU Dept 4000, PO Box 6050, Fargo, ND 58108-6050.

Thank you for your taking part in this research. If you wish to receive a copy of the results, please let me know by e-mail (kamran.khanzada@ndsu.edu).

Kamran Khanzada