A Tentative National Infrastructure Policy for Canada

by

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A TENTATIVE NATIONAL INFRASTRUCTURE POLICY FOR CANADA

ABSTRACT

Throughout history, a well maintained and functioning infrastructure has successfully contributed to Canada's international competitiveness and high standards of living, however, this infrastructure has deteriorated significantly and it poses a threat to Canada's productivity, international competitiveness, economic development and the quality of life of all Canadians. Neglect of Canada's infrastructure over the past several decades has resulted in accelerated deterioration and has caused many assets to become obsolete, unsafe or no longer serviceable long before the end of their service life. The recent, tragic infrastructure failures and distresses reflect these years of neglect and reveal the urgency of bringing infrastructure back to acceptable levels of safety and serviceability. This thesis proposes that a National Infrastructure Policy be developed as a first step towards this improvement. The need for a policy is highlighted by reviewing some of the main findings of the 2007 *FCM-McGill Infrastructure Survey* and the current trends in infrastructure management. The policy will address the current trends and shortfalls and provide long-term, sustainable solutions to dealing with the infrastructure crisis in a standardized manner nation-wide.

UNE PROPOSITION POUR UNE POLITIQUE NATIONALE D'INFRASTRUCTURE POUR LE CANADA

RÉSUMÉ

Tout au long de l'histoire, une infrastructure efficace et bien entretenue a contribué à la compétitivité internationale du Canada ainsi qu'à l'élévation de son niveau de vie. Cependant, cette infrastructure s'est sensiblement détériorée et est devenue une menace pour la productivité du Canada, pour sa compétitivité internationale, son développement économique et la qualité de vie de tous les Canadiens. La négligence à ce sujet durant ces dernières décennies a provoqué une détérioration rapide et rendu de nombreuses structures obsolètes, dangereuses voir même inutilisables bien avant la fin supposée de leur durée de vie. Les récents sinistres et tragiques défaillances dénoncent ces années de négligence et révèlent un besoin urgent de remettre l'infrastructure canadienne à des niveaux de sécurité et de service acceptables. Cette thèse propose qu'une Politique Nationale d'Infrastructure soit mise en place comme première étape vers cette amélioration. Le besoin d'une telle politique est mis en évidence par certains des principaux résultats de *l'Enquête FCM-McGill sur les Infrastructures Municipales - 2007* et par la tendance actuelle de gestion des infrastructures. Cette politique abordera les tendances et insuffisances actuelles et fournira des solutions durables afin de traiter la crise de l'infrastructure d'une manière standardisée à l'échelle nationale.

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CHAPTER 1

THE INFRASTRUCTURE CRISIS

1.1 Introduction

History of Canada's infrastructure dates back to the early days of the confederation. Over the past years, these infrastructure facilities have successfully enhanced Canada's productivity, international competitiveness, economic growth and high standards of living. However, despite its crucial role, Canada's infrastructure has been neglected in the past few decades and the resulting accelerated deterioration has caused many facilities to become unsafe or no longer serviceable long before the end of the expected service life. The recent, tragic infrastructure failures and distresses reflect these years of neglect and reveal the urgency of bringing infrastructure back to acceptable levels of safety and serviceability. The de la Concorde Overpass collapse occurred on September 30, 2006 in Laval, Quebec, north of Montreal, killing five people and injuring six others. The latter is one of many bridge failures in Canada's history that occurred prior to the midpoint of the bridge's intended service life; it failed after 36 years in service. The Minnesota Bridge collapse, which occurred on August 1st, 2007 after 40 years of service, is a similar example proving that our North American neighbours are experiencing a similar crisis.

Canada saw a boom in infrastructure construction in the post-war period. This infrastructure has reached the end of its useful service life, but the backlog of deterioration that has accumulated over the years has also led to the rapid aging of our "younger" assets. Therefore, the poor state of the older and newer facilities, combined, have lead to greater needs and have amplified the projected costs of bringing the infrastructure back to acceptable levels. This backlog of deterioration is primarily due to lack of funding in the area of municipal works over the years, which has consequently led to years of deferred maintenance. Figure 1.1 shows that if a routine maintenance program is not implemented throughout a facility's service life, then deterioration initiates at an early stage (Phase B), the asset will then continue to deteriorate at rapid rates (Phase C). This will not only lead to rapid aging of the asset, but to exorbitant costs for the needed repairs and rehabilitation (Phases C and D). If needed maintenance, repair or rehabilitation is deferred, the asset will typically reach the point where rehabilitation will no longer be possible, and the facility will need to be replaced at much higher costs (end of Phase D).

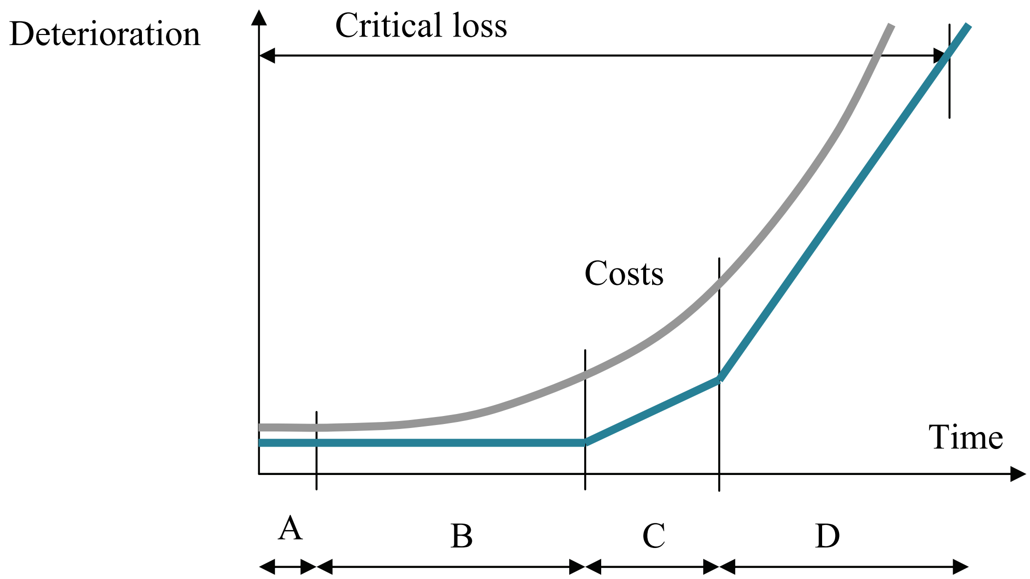

Figure 1.1 The onset of deterioration and its impact on the costs for maintenance, repair and rehabilitation (CEB, 1989).

1.2 The Age of Canada's Infrastructure

The service life of an infrastructure asset is defined as the period of time over which the asset is able to provide an acceptable level of performance with regular, routine maintenance. The service life attained by the infrastructure would depend on the quality of design, construction, operation, maintenance practices, misuse and abuse, and environmental factors. According to the *Technology Road Map* (TRM), more than half (59%) of the infrastructure in Canada had already reached or exceeded half of its service life in 2003: about 31% of the infrastructure was between 40 and 80 years old, 28% between 80 and 100 years old, and only 41% less than 40 years old (Figure 1.2) (TRM, 2003). The TRM was established by four national groups - the Canadian Society for Civil Engineering (CSCE), the National Research Council (NRC), the Canadian Council of Professional Engineers (CCPE), now Engineers Canada, and the Canadian Public Works Association (CPWA) – who are working together to identify the challenges and associated technological needs of Canada's infrastructure systems over a ten year period.

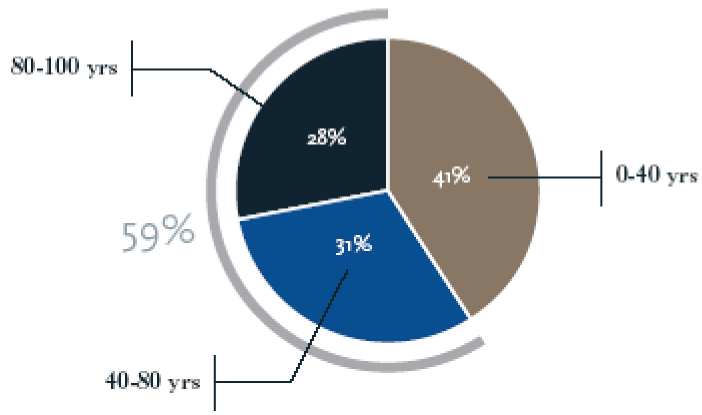

Figure 1.2 The age of Canada's municipal infrastructure (TRM, 2003).

A 2006 Statistics Canada report reveals that since 2003 the average age of infrastructure has actually decreased due to increased government spending. While this last statement would suggest that actions are being taken to restore existing infrastructure to acceptable levels, it must be noted that it is the investment in constructing new infrastructure that has helped lower the average age. The average age was calculated based on several factors: investment, the survival function, the year the investment was made, and the year-end gross capital stock (Gaudreault and Lemire, 2006). The report suggests that in 2003, more than half of the useful service life of four infrastructure categories had been reached. The elapsed useful life, in 2003, of each of the main infrastructure categories are as follows (Table 1.1).

Table 1.1 The elapsed useful life of four infrastructure categories in 2003 (Gaudreault and Lemire, 2006).

Infrastructure Category	Elapsed useful life in 2003
Wastewater treatment facilities	63%
Roads and highways	59%
Sewer systems	52%
Bridges	49%

The authors only considered four infrastructure categories because "combined, they comprised 80% of all engineering infrastructure owned and operated by federal, provincial, territorial and municipal governments in 2002" (Gaudreault and Lemire, 2006). Wastewater treatment facilities have undergone the most aging, not having been subjected to any major investments since the late 1970s. Yet, the overall average age of the four infrastructure categories combined has increased at the national level. Figure 1.3 shows the trend in average age over a forty year span, since 1963.

Most of the infrastructure was built in the post-World War II period, thus investments in new infrastructure decreased in the 1970s and 1980s, and investment in the maintenance of assets was minimal. As a result, the most aging took place during the 1970s and 1980s. Aging slowed after this period, due to increased investment in infrastructure to meet new needs resulting from suburban sprawl, urbanization, population growth, etc. The 1990s also saw an increase in the infrastructure's average age, but at a considerably lower rate. Increased investment for new construction in the past decade has maintained the average age at stable rates.

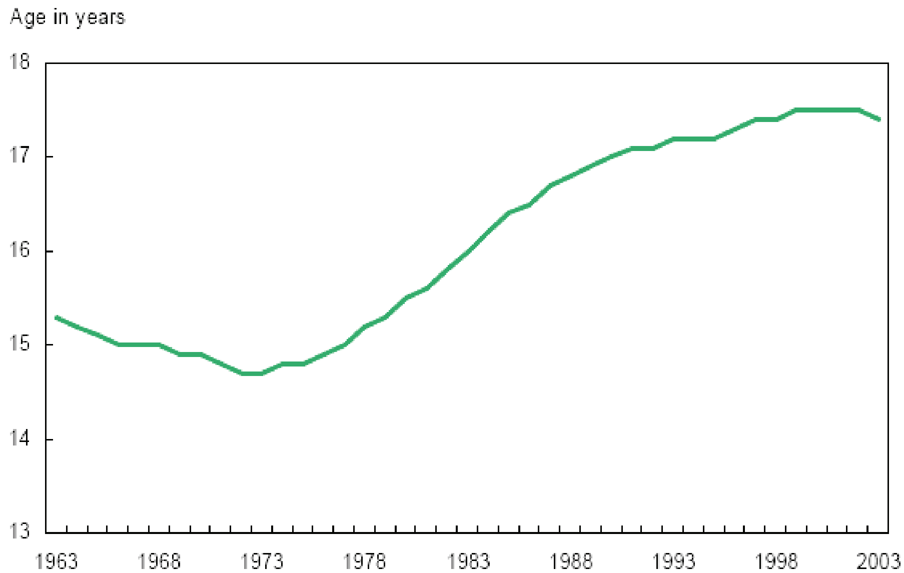

Figure 1.3 The average age of four infrastructure categories from 1963 to 2003 (wastewater treatment facilities, roads and highways, sewer systems and bridges) (Gaudreault and Lemire, 2006).

Table 1.2 gives the investment breakdown by different jurisdictions (federal, provincial, territorial and municipal) from 1992 to 1997, for both new construction and upgrading of existing infrastructure. Approximately 80% to 90% of infrastructure investments by all levels of government were for the construction of new infrastructure. Investments towards repair and rehabilitation have been the greatest for roads, highways and bridges, which based on past infrastructure surveys have been in the greatest need for repair. The greatest investments for new construction have been for the construction of wastewater treatment facilities, which have the highest average age and sewer systems, which have undergone the fastest rate of growth within the municipal infrastructure stock due to urbanization and population growth (Gaudreault and Lemire, 2006).

Table 1.2 Average investment by each level of government for new construction and upgrading of existing infrastructure, from 1992-1997 (Gaudreault and Lemire, 2006).

	Municipal		Provincial		Federal	
	New construction	Renovations	New construction	Renovations	New construction	Renovations
	%					
Roads and highways	81	19	80	20	68	32
Sewer systems	88	12	84	16	99	1
Wastewater treatment facilities	96	4	85	15	98	2
Bridges	85	15	68	32	77	23
Total[1]	**88**	**12**	**79**	**21**	**86**	**14**

1. Total for the four components.

Although the above numbers provide a general idea of the average age of some of the infrastructure assets in Canada, it is difficult to scientifically assess the average age of all of Canada's infrastructure stock, given that a complete national inventory of the infrastructure stock is non-existent. Municipalities across Canada have not maintained inventories of the infrastructure assets in their communities. The construction specifications and financial data of many facilities are now being archived, however, much of the documentation pertaining to the older facilities does not exist. Therefore, while the overall condition of visible structures can be assessed, the state of underground infrastructure is often unknown, and in some cases, the exact location or even the existence of many underground utilities remains uncertain. The lack of standard condition assessment techniques for all municipalities also leads to uncertainties, given the subjectivity of many evaluations, and therefore, the inaccuracy of available infrastructure assessments. Together, the lack of a complete national inventory and of national standardized condition assessment techniques makes it difficult to accurately identify the areas with the greatest needs, and therefore, to accurately get an overall assessment of the present infrastructure crisis.

1.3 The Infrastructure Deficit

Some groups have tried to quantify the infrastructure crisis in terms of the municipal infrastructure deficit. This figure does not encompass infrastructure owned by the other orders of government (e.g., hospitals, schools, military bases, port infrastructure), but only those assets owned and managed by the municipalities. Including infrastructure from other orders of government would be a very difficult task. In particular, information retrieval would be complex and the country's incomplete infrastructure inventory would yield a less accurate estimate of the deficit. Therefore, it is typical to find the municipal infrastructure deficit as a separate figure than that which represents the needs of other specific infrastructure categories owned and operated by specific groups or other levels of government (e.g., waterfront/port infrastructure, provincial highways, etc.).

Table 1.3 summarizes the deficits derived from some recent studies by various groups. First, in 1985, the Federation of Canadian Municipalities (FCM) developed a survey to gather information from the various municipalities across Canada regarding their infrastructure financing and other management practices, and found a municipal infrastructure deficit of $12 billion. In 1992, the deficit increased to $20 billion. Only three years later this estimate was revised and found to be $44 billion, this time with a more comprehensive survey developed by the FCM and McGill University. In 2003, various groups got together, among these the Canadian Society for Civil Engineering (CSCE) and the National Research Council (NRC) and upgraded the McGill-FCM estimate to $57 billion. The Toronto-Dominion (TD) Bank Financial Group has estimated the deficit to be about $60 billion, and increasing at the rate of $2 billion a year since 2003 (Mirza, 2007). However, estimates of the deficits for specific infrastructure categories, derived from specialized groups (e.g., CWWA, CUTA, etc.) suggest that rapid deterioration and, consequently, rapid aging have led this figure to compound significantly over the past five years.

Table 1.3 The escalating municipal infrastructure deficit obtained from various studies.

Year	Deficit ($ Billion)	Group
1985	12	FCM survey results
1992	20	FCM survey results
1996	44	Detailed FCM- McGill survey results
2003	57	Technology Road Map (TRM): Upgrading of FCM- McGill survey results.

The *2007 FCM-McGill Municipal Infrastructure Survey* has confirmed that the deficit has escalated dramatically since the $60 billion estimate of 2003. If the recent tragic events and resulting deaths have not been motivating enough to include infrastructure among the list of priorities on political agenda, at $123.6 billion, this revised estimate should be sounding an alarm that there is a need for urgent action. Unlike past surveys, the *2007 FCM-McGill Municipal Infrastructure Survey* also established the new needs of communities across the country. The capital needs for new infrastructure and for the expansion of existing infrastructure to meet new needs was found to be $115.2 billion. While this value cannot be compared to any past estimates, it is believed that this need is compounding at a rate similar to that of the deficit for upgrading existing infrastructure. As a result, Canadian citizens not only have to deal with using deteriorated infrastructure on a daily basis, but even where infrastructure is in an acceptable state, they must deal with the consequences of its inadequate capacity to meet the required levels of serviceability (e.g., congestion and delays where populations are high and transportation and transit systems are inadequate, minimal options where sports complexes and recreational facilities are scarce but in high demand, etc.).

1.4 Infrastructure Tragedies

The de la Concorde Overpass and the Minnesota Bridge collapses are only two of the many infrastructure-related tragic events experienced by North Americans over the past century. Together, they are also examples of only one type of infrastructure system that has failed before society's eyes. Water supply contaminations, pipe bursts and transit accidents are among the other tragedies that have affected communities and that continue to remind citizens of how often infrastructure is taken for granted and how important it really is to the everyday functioning of a society. Transit accidents can paralyze a city, which can leave many without the possibility of getting to school or work and, even for a day, can mean thousands of dollars lost for a business. An increasing amount of people fear driving over bridges and today, many would be keen on the idea of their municipalities adopting user-pay models such as toll booths if it meant that the safety of bridges and highways would be ensured. The latter would have caused public uproar by the majority of the population only ten years back. Water tragedies such as the Walkerton case have left many fearful and with a lack of trust in their water supply and treatment systems. In addition, many people are still suffering from permanent kidney injuries due to this outbreak.

Appendix A provides tables of the major bridge failures, water outbreaks and transit and rail accidents that have occurred in Canada. As bridge failures are the most common and frequent type of infrastructure failures to make international news, a table detailing popular international bridge failures is also provided.

*1.4.1. **Bridge Failures***

Unfortunately, despite the several tragedies, not much has changed and the politicians have taken no significant actions or policy decisions. Approximately 96 injuries and 108 deaths have resulted from bridge and highway collapses in Canada since 1900 and many more injuries and deaths have resulted from bridge failures around the world. Approximately 40 major international bridge and highway collapses have occurred since 1900 in countries such as the U.S., India, Sweden, Wales, Australia, Russia, Spain, Korea, Palau, Israel, Portugal, Japan, Guinea and Pakistan. An amazing 16 of these 40 failures have occurred since the year 2000! Of the 40 bridge collapses that have occurred in Canada and the U.S., 10 of these occurred during construction and one during decommissioning. All major Canadian and international bridge collapses are summarized in Tables A.1 and A.2 of *Appendix A*.

Trends can be established when analyzing the main causes of bridge failures at different points in time. Construction errors and design flaws were noted to be the typical causes for the earlier bridge failures between 1900 and 1940, as many bridge designs and bridge construction practices were being introduced. For example:

- The Quebec Bridge collapsed in 1907, killing 75 people and injuring 11 others. The dead load of the bridge was underestimated, a mistake that was not identified, as preliminary calculations were not re-verified prior to construction. On-site inspections by experienced supervisors were minimal and the primary responsibility of a recent graduate. Additionally, some installed members had defects (Ricketts, 2007).
- The Second Narrows Bridge collapsed in Vancouver, British Columbia in 1930 due primarily to poor planning and design. The bridge was not designed with adequate fender systems and an appropriate clear span between high tide water levels and the bridge deck, for the shipping activities in the area. As a result, the bridge was hit many times by ships; the last barge to hit the bridge was pushed up under the span during high tide, taking away the centre span. There were 8 deaths and 20 people injured as a result of this accident (Bouton, 2008).
- Timber forms used in the construction of the Sandö Bridge in 1939, in Sandö, Sweden, were not securely installed and all scaffolding collapsed under the weight of the fresh concrete, killing 18 workers (University of Cambridge, 2008).

Lack of experience continued to be a cause for the subsequent collapses occurring between the 1940s and the 1970s; more precisely design errors, inadequate construction practices and inappropriate use of materials were the main causes. Examples of bridges that collapsed during this era include:

- The Heron Road Bridge which collapsed in 1966 in Ottawa, Ontario during construction of the bridge, killing nine workers and injuring 57 others. The wooden support forms lacked diagonal bracings and green lumber was used (Laucius, 2006).
- The Silver Bridge Collapse connecting Point Pleasant, West Virginia to Kanauga, Ohio, which collapsed in 1967 and killed 46 people and injured nine others. One of the steel eye-bar suspension chains had a crack, making poor quality control during construction one of the main causes of the collapse. However, had the bridge been designed appropriately from a maintenance point of view, the severity of this crack growing over the years due to stress corrosion and corrosion fatigue would have been apparent during inspections. Advanced inspection techniques were unavailable during this time and the only way to have spotted the crack was to disassemble the eye-bar (Corrosion Doctors, 2007).

As expected, negligent construction practices, inadequate inspection techniques and deferred maintenance were the primary causes of collapses occurring after the 1970s. Today, almost 40 years later, deferred maintenance continues to be the leading cause for bridge collapses typically after 30 to 40 years of service life; these bridges should have been serviceable for 75 to 100 years. For example:

- In North America, the de la Concorde Overpass and Minnesota bridges collapsed after 36 and 40 years of service, respectively. Though not the sole cause, deferred maintenance was a primary cause of both tragedies. Together, these failures took the lives of 17 people.

- The Seongsu Bridge collapsed in Seoul City, Korea in 1994 after only 15 years of service. The bridge was highly corroded due to use of de-icing salts and no maintenance or inspection standards were ever specified for this bridge. Thirty-two people died and 17 others were injured (Kunishima, 2007).
- Though the age of the bridge is not specified, the Daman Bridge in Daman, India collapsed in 2003 due to similar reasons, killing 25 people (23 of whom were children) and injuring another 20 people. The bridge had been in a state of disrepair for some time, but proper actions were not taken to restore the bridge to acceptable levels (BBC News, 2003).

The most unacceptable part of the current infrastructure crisis is that people (including politicians) are aware that it is happening, yet history keeps repeating itself. Prior to the 2001 Portugal Bridge Collapse, which killed 70 people, Mr. Paulo Teixeira, the mayor of Castelo de Paiva (one of the two towns linked by the bridge), had reportedly warned the government that the bridge was unsafe (BBC News, 2001). If the latter warnings were not convincing enough, the fact that the bridge was 116 years old should have increased the priority of performing detailed inspections and condition assessments of the bridge.

Similarly, Minnesota officials had been warned as early as 17 years prior to the incident that the bridge was "structurally deficient". In those 17 years, only small scale repairs and inspections were performed. Two years prior to the bridge collapse, the Department of Transportation has repeated these warnings, urging for frequent and detailed inspections of the bridge's trusses (Keen, 2007). Investigation into the causes of the bridge collapse revealed that sixteen fractured gusset plates in the central span of the bridge were the main cause of the collapse. These plates were also found to be only half of the required thickness, making design flaws another cause (McCarthy, 2008). In addition to the extra weight on the bridge due to construction, its "poor condition" – a term used to describe the bridge's supporting structure in an inspection one year prior to collapse – is also to blame; the bridge was rated at four out of nine, where zero means that the structure requires a shutdown and nine means that it is in a perfect state (Wald and Chang, 2007).

*1.4.2. **Transit System Accidents***

The 1896 Victoria Streetcar accident is considered to be "the worst streetcar accident in Canadian history". A streetcar designed to hold 60 passengers was packed with 142 passengers, causing the wooden Pointe Ellice Bridge, over which it was passing to collapse, killing 55 persons. Negligent practices and operations have unfortunately been the cause of the Point Ellice Bridge collapse and the later transit accidents as well. However, in addition to negligent practices, faulty machinery and deterioration have largely contributed to the causes of the largest transit accidents in Canada.

In 1995, Toronto experienced the "worst subway accident in Canadian history", which killed three and injured 36 people. A new driver ran three red lights before depending on a fail-safe trip arm that did not function (Craig, 1995). Similarly, the Montreal Metro accident of 1971 was due to a faulty throttle that prevented proper functioning of the brakes, leading to a collision between two metro cars. Inadequate ventilation in the metro tunnel was another detrimental factor, leading to a fire lasting 17 hours. Firefighters had no choice but to flood the metro tunnel, damaging much of the infrastructure, including the rolling stock. In addition to the $7 million damage and firefighting costs, 35 injuries and surprisingly only one death were the outcome of this metro tragedy (Halton, 1971). The second subway accident in Toronto occurred in 2007 when a subway car was being used to push a flatbed car holding metal scaffolding that had been used for tunnel repairs during the day. The heavy metal was not securely fastened to the flatbed, causing it to fall onto the back metro car, killing the driver and injuring two other passengers.

Internationally, other major cities such as Valencia, Rome, Tokyo and London have had similar transit accidents. Two Tokyo trains collided in 2000, killing four people and injuring 40 others. In London, a subway train collided into the dead end of a tunnel in 1975, killing 43 people (Craig, 1995). The Valencia transit accident (2006) was due to derailing of a metro car, killing 41 people. In the same year, over 100 people were injured and one person died during another metro collision in Rome. The latter was reportedly due to faulty brakes and inadequate training of the personnel (RaiNews 24, 2006). Therefore, just as in the case of bridge failures, common trends can be seen when analyzing transit accidents, but yet again history keeps repeating itself (Table A.3, *Appendix A*).

1.4.3. ***Water Supply Contaminations***

There have been seven deaths and more than 25,000 cases of illness from water supply system contaminations in Canada since 1996. However, the list of contamination outbreaks both in Canada and internationally does not end here. Tables A.4 and A.5 in *Appendix A* detail only some of the major outbreaks of pathogenic bacteria due to water contamination in Canada and internationally, respectively. Among the worst and recent water supply contaminations in Canadian history are the 2000 Walkerton Tragedy, which occurred in Walkerton, Ontario and the 2001 North Battleford cryptosporidium parasite contamination, which occurred in North Battleford, Saskatchewan. Together, these tragedies have led to seven deaths, approximately 8000 cases of illness and millions of dollars lost in medical costs, compensations, law suits and deferred infrastructure upgrades; timely upgrades would have cost less and could have prevented such tragedies from happening altogether.

In Walkerton, one of the three wells supplying water to the community was shallower, which according to the Ontario Environment Minister was the reason to install a chlorination piping system at this well. This chlorination system was never installed, and the well was found to be in close proximity of a cattle farm. Therefore, during a period of unusually high rainfall cow manure was swept into the well. To make matters worse, the water chlorination system at the treatment plant had not worked properly for some time. In addition, the management was not qualified and did not have the knowledge, or training required when faced with the problems at the treatment plant, or in the event of a contamination. The Walkerton example shows the diversity of the causes of this tragedy: poor planning, design errors, inadequate maintenance, deteriorated and obsolete infrastructure, lack of quality control, negligent operations and unqualified personnel, political inaction and inadequate levels of treatment.

The North Battleford contamination resulted from similar causes. These events suggest that the society is not learning from its past mistakes, and in the 21st century, with the ready availability of newer technologies and greater knowledge, such tragedies are only getting worse. An examination of the main causes of these outbreaks (*Appendix A*) in Canada and around the world clearly shows that some of the causes of the older water supply contaminations have combined to cause most of the recent tragedies:

- The cryptosporidium parasite contamination in North Battleford, Saskatechewan in 2001 was due to a combination of factors, namely, design errors (the treatment plant was built only 2 km downstream of the sewage treatment plant), inadequate maintenance of the treatment plant, inadequately trained personnel and management, and political inaction, as there were warnings as early as 1997 that the effluent being discharged was not meeting the environmental standards. The contamination caused 6000-7000 cases of illness and over $18 million in compensations and infrastructure upgrades (CBC, June 10, 2007).
- Other cryptosporidium outbreaks occurred in Cranbrook, British Columbia and in Kelowna, British Columbia in 1996, causing 2000 and 10,000-15,000 cases of illness, respectively. Both were due to a combination of poor planning and inadequate treatment levels. Freshwater sources in both cases were contaminated by livestock feces (CBC, 2004).
- The 1993 cryptosporidium outbreak in Milwaukee, in 1993 led to 403,000 cases of illness and over 100 deaths. Again, a combination of factors - negligent operations and inadequate treatment – led to this tragedy. One of two city water purification plants was contaminated with sewage and the plant operated under abnormal turbidity levels for a little over two weeks (Blair, 1995).

- Another cryptosporidium and giardia outbreak in Sydney, Australia, which occurred in 1998, also due to negligent operations and inadequate treatment levels, affected three million people and cost tens of millions of dollars (public inquiry, liability settlements, etc.) (Leiss, 2007).

While water supply contaminations usually have the gravest outcomes, other failures related to water supply and sewage disposal infrastructure are possible. It is estimated that in Montreal close to 50% of treated water is lost in some districts due to leaking pipes, leading to large financial and energy loses and possible contamination of the water supply. However, the severely cracked and deteriorated pipes can result in structural failure of the system, which can also lead to serious consequences. For example, the pipe burst on Pie-IX Boulevard in Montreal Quebec, in 2002, flooded 250 homes and caused distress to 22,000 people, who were left without drinking water for nine days and were left with their basements and possessions destroyed. It cost the City of Montreal $8 million to compensate the affected citizens for this damage (CTV News, 2004).

1.4.4. ***Rail Accidents***

The world's deadliest rail accidents between 1915 and 2005 are listed in Table A.6 (*Appendix A*). While Canada does not make this list, Table A.7 shows that Canadians have had their share of rail accidents. The lengthy table may come as a shock to many people, as it briefly summarizes the rail accidents that have occurred since 1991. There have been over 120 rail accidents since that time, many of them not making national news as they involve no fatalities or injuries. Nevertheless, the causes of these accidents are examples of the poor state of the rail infrastructure across Canada. Causes include:

- Numerous derailments due to deteriorated railway tracks and ties, depressions caused by failure of the track's subgrade, poor welding, track buckling, etc.;
- Inadequate control systems and technologies;
- Negligence on the part of crew members in the yard;

- Failure of conductors to follow speed limits and other specified regulations;
- Conductor fatigue due to long shifts;
- Faulty infrastructure, such as hand-breaks, switch-activated rails, computer-assisted train control systems, warning signals at crossings, etc.; and
- Unsafe or poorly designed pedestrian and vehicle crossings.

While fatalities and injuries are less than those reported in the world's deadliest rail accidents, the fact that some did occur should not be ignored. These accidents had direct, serious impacts on the society and in many cases, they resulted in large costs associated with property damage and deterioration of the environment due to the resulting numerous oil and gas leaks.

A 2006 equipment inspection by Transport Canada revealed that 20.6% of 3,021 freight cars and 53.9% of 232 locomotives inspected suffered from safety defects. These inspections revealed 151 defects pertaining to safety and another 145 defects pertaining to brake gear defects. An additional 60 defects were found related to the car bodies. Similar inspections of locomotives revealed 80 defects pertaining to brake gear, 28 pertaining to air brakes, and 72 related to combustible materials (i.e., excessive accumulation of oil on the exterior of the locomotive, or the fuel tank) (Transport Canada, July 29 2007). A historical overview of the infrastructure in Canada (Chapter 2) would further elaborate the deficiencies in railway infrastructure. Rail systems are amongst the oldest infrastructure types, and the deterioration and rapid aging due to inadequate maintenance, repair and rehabilitation to upgrade the system due to lack of funding and other reasons can possibly explain these numerous defects. Additionally, with the advent of airplanes and other modes of transit, dependence on rail systems decreased considerably.

CHAPTER 2

INFRASTRUCTURE IN CANADA: A HISTORICAL OVERVIEW

2.1 Introduction

Significant events in Canadian history can be directly associated with the development of infrastructure across the country. High immigration rates and settlement in Canada followed the construction of railways, which permitted access to regions other than those once solely accessible by boat. Over time, even remote areas of the North became accessible with the construction of railways and the advent of aviation, which required the development of new infrastructure. The development of road networks, including highways and bridges, further enabled access to new lands, new resources and subsequently, the development of communities and industries across the country.

As Canada's major cities were founded and the populations continued to grow, inter-city and urban transit systems were required to help shape the metropolitan communities. Presently, transit and other systems linking intermodal transportation networks remain major points of interest for citizens or business owners seeking to find a new place to live, or to work, to establish a company, or a new business. Consequently, the on-going improvement of the infrastructure, management and operations of these systems to ensure their efficacy and serviceability must remain high on political agendas for cities to remain competitive and provide a good quality of life to their citizens.

Transportation infrastructure plays the most visible role in everyday life. Water supply and sewage disposal systems are out of sight and normally taken for granted, along with other associated infrastructure (e.g., treatment plants); these facilities have improved considerably over the decades. The earlier systems are unimaginable to the present generation. A review of the progress of infrastructure facilities over the decades will reveal how Canadian communities have surpassed an era of pain and suffering caused by spreads of waterborne epidemics.

Unfortunately, many communities across the globe are still living in unacceptable conditions, with no water supply and sewage disposal systems, or water treatment processes. Yet, North American-modern-day systems set high standards for their water services, providing for high standards of living.

Economic development and the standard of living of a community are directly related to the infrastructure that serves the community's population on a daily basis. The following chapters will summarize the most significant events in the development of infrastructure in Canada, revealing its growth into one of the leading countries among the most prosperous, commercially active and attractive in terms of living conditions.

2.2 Transportation

Explorers and settlers arrived from Europe in the 1500's and quickly became familiar with the canals, rivers, streams and lakes used by the natives for travel by canoe. These explorers and settlers introduced other forms of inland transportation including horses, oxcarts and homemade carriages, which multiplied when graded roads/trails were created. The first graded road in Canada was a 16 km military road built in Nova Scotia, by Samuel de Champlain in 1606. Similarly, the few roads constructed in the 1700's were also built as military trails, including a road built in the 1730's linking Montreal and Quebec City, which took four and a half days to travel by carriage, and Yonge Street – now a major artery in Toronto, Ontario. However, road construction really accelerated in the 1800's following an appropriation made in 1804 for road construction and the introduction of toll roads. Prior to this date, in the late 1700's, settlers were responsible for maintaining the roads adjacent to their properties (Day, 2007).

Although transportation by water was still the primary travel mode; construction of roads enabled further inland access and reduced local travelling costs. The earlier, poor condition of roads swayed people to solely use this option for local, nearby travel. For longer trips, water transport and railways, which were introduced in the 1830's, were better alternatives. Railways encouraged development in Western Canada, in areas other than those accessible by boat and provided another means of travel during the winter months when ice often prevented water transportation. Subsequently, road construction commenced in British Columbia, the Northwest Territories and the Prairie Provinces, between 1850 and 1900. Until that time, Indian trails had provided sufficient inland access (Gilchrist, 2007).

The construction of railways in Canada was the first step towards the creation of urban and rural communities, industrial sectors and business districts; it constituted a progressive step towards the development of the country. The debt that railway construction imposed in Prince Edward Island, actually led the colony to join the Confederation, and become a province of Canada in 1873. As cities were formed and the railway network grew, the need for extended roads, tunnels and highways became apparent. The introduction of early forms of urban transit, to respond to large population increases in urban areas, had a similar effect. The first horse-drawn trams were quickly replaced with inventions such as trams, tramways or streetcars (steel-wheel vehicles on rail) and trolleybuses (rubber-tired electric vehicles), prior to adopting buses.

Few of these traditional forms of transport exist today; extended bus routes and subway systems generally serve Canada's major cities. Modern-day transit systems consist of a combination of services that complement one another and provide acceptably frequent service to citizens. Modern light rail systems are systems comprise electric cars which carry lighter loads (i.e., passengers versus freight) at faster speeds, such as the Calgary C-Train, Edmonton's light rail system, Toronto's streetcars and Ottawa's O-train. Rapid transit systems are electric railway systems that are grade-separated from street traffic, thereby avoiding congestion in the more populated cities (e.g., the Montreal Metro, Toronto subway and the Vancouver Skytrain). Without these modern forms of transit, Canada's major cities would not be able to flourish and be competitive nationally and internationally.

2.2.1. ***Rail***

The railway transportation system has played a very important role in the shaping of urban communities and industrialization in Canada. A primitive railroad was constructed on Cape Breton Island, Nova Scotia, by French engineers in the 1720's. The railroad consisted of two wooden rails, which supported horse-drawn carts on wheels and was used to transport material from an abandoned gypsum mine to a building site. The use of wooden tracks was maintained, but the use of horse-drawn carts was abandoned with the advent of steam engines.

Steam power was first employed on railroads during the construction of Quebec's Citadel in the 1820's. Initially, the steam engine was stationary and supplied power to moving cable cars, which transported stones up and down a hill on wooden double tracks. The Canadians soon mirrored the English by employing steam engines on rail, a discovery that was made in 1804 (Mika and Mika, 1985). However, initial debates related to railway construction in Canada were not related to the design choice, but to the controversial views of citizens who were still questioning whether this type of transportation should be employed at all.

Two newspapers clearly reported the two opposing views. The *Quebec Mercury* expressed the general consensus that constructing new canals and improving navigation along the existing waterways would be more convenient and economical than building a railway system. In its December 1st, 1824 issue, the *Montreal Gazette* clearly pointed out the economical burden because of the faulty canal construction. The Gazette used the example of the locks at the Coteau-Du-Lac, which like other locks built during that time were expensive, too narrow and had to be rebuilt if they were to service larger vessels. Additionally, the newspaper outlined the costs of building the Lachine Canal and the Military Canal at Granville, which were much greater than the proposed cost of constructing a railroad (Mika and Mika, 1985).

The *Quebec Mercury* article clearly showed that the general consensus of the public was not based on an analysis of the benefits brought by the railroads to some European countries. The public also failed to consider how the railroads would eliminate the inconveniences associated with the existing modes of travel, namely the impediments caused by the winter climate on waterways and travel by horse-drawn carriage, and the danger and inconveniences caused by the rapids. The public did not envision the advantages of the railroads to enable convenient travel and to develop new settlements; populated communities had been concentrated around waterways in Ontario, Quebec and the Maritime Provinces.

2.2.1.1. The Beginning of the Railway Era: Far From Perfect

Construction of the Champlain and St. Lawrence Railroad – Canada's first railway – was the result of the persistence of a group of Montreal businessmen, who believed that a railroad was the key to success and national prosperity. Among these men and stockholders were John Molson, Montreal brewer and steamboat owner, Peter McGill, President of the Bank of Montreal; and Jason C. Pierce, a wealthy merchant who urged that plans to construct the railway be carried out after being shelved for some years due to some more urgent matters, including an election riot in Montreal and a cholera outbreak (Mika and Mika, 1985).

The 24 km railroad, linking Laprairie on the St. Lawrence River with St. Jean on the Richelieu River went into service in 1836 and remained the sole railroad in Canada for 10 years (Dorin, 1975). The wooden wheels of the steam locomotive ran on wooden rails strapped with iron. Although far from being perfect, the overall public opinion of railroads changed. The locomotive only reached speeds of 32 to 48 km/hr, did not arrive at stops on time, derailed frequently (without causing much damage, except in one instance) and the wood-burning engine "puffed" thick clouds of smoke and cinders onto nearby neighbourhoods and its passengers. Additionally, "in the early days during heavy snowfall, passengers often had to disembark and help push the train when [it] was unable to make it up the hill on her own", and at many times travel had to be suspended due to poor weather conditions (Mika and Mika, 1985). However, complaints were minimal as citizens were quickly intrigued and convinced by the new form of transportation. This increased popularity was reflected by high passenger and freight traffic, resulting in a need for extended lines and additional locomotives.

The railways constructed in the following years included the Montreal and Lachine Railroad (1847), the St. Lawrence and Atlantic Railroad (1853), the Great Western Railway (1854), and the Grand Trunk Railway (1860). Each railway was constructed expecting that they would attain the popularity of the Champlain and St. Lawrence railways. The Grand Trunk Railway (GTR), in particular, was one of the greatest achievements in railway history at that time. The railway ran from Sarnia, Ontario to Riviere-du-Loup, Quebec, and from Montreal, Quebec to Portland, Maine. At over 1,528 km in length, the GTR was the longest system in the World and was effective in linking Canadian cities to each other and to the United States (Monaghan, 2007).

2.2.1.2. The Second Phase of Railway Construction

The railways that came before and after Confederation continued to reach new boundaries in the history of railway construction. The Intercolonial Railway (1876), owned and operated by the federal government and funded by British Loans, came with Confederation and connected Halifax with Atlantic Canada, Ontario and Quebec. The Intercolonial was the result of a reference in the 1867 British North American Act outlining "the central government's responsibility to physically connect Nova Scotia, New Brunswick, Quebec and Ontario with a railway line" (Monaghan, 2007).

Railway construction in the West came after Confederation and brought commercial activity in the areas of agriculture and timber production, improving the economic development throughout the country. The Canadian Pacific Railway (CPR), owned by the Canadian Pacific Railway Co., was the first railway connecting central Canada with the Pacific coast, and soon extensions were made to the Atlantic Provinces. Constructed between 1881 and 1885, the CPR brought high levels of immigrants to the Western parts of Canada, leading to the creation of many cities in British Columbia and the Prairie Provinces. Agriculture boomed due to the high immigration rates and the resulting high economic activity necessitated further railway expansion (Marsh, 2007). Construction of the Canadian Northern Railway, the National Transcontinental Railway (from Winnipeg to Moncton) and the Grand Trunk Pacific Railway in the following years brought total railway lengths from 16,000 km in 1872 to over 57,000 km by 1920 (Monaghan, 2007). Although owned and funded primarily by private companies or individuals, the railways had the support of the federal and provincial governments, which also helped fund these railway projects through cash grants and bonds.

2.2.1.3. Influence of the Two World Wars

The First World War led to a decline in immigration levels and funds for new projects. As a result, the Intercolonial, the National Transcontinental, the Old Grand Trunk, the Grand Trunk Pacific and the Canadian Northern were grouped into one system – the Canadian National Railways – a national system now owned by the Canadian government that provided for greater funding to keep these systems operating (Marsh, 2007). Although new technologies were developing (diesel electric locomotives replaced steam-powered locomotives and steel replaced most wood construction), railway expansion declined following both wars. In 1969, the railway system had only expanded by an additional 8,400 km (Monaghan, 2007).

2.2.1.4. Modern Day Systems

The face of railways has changed significantly from the earlier years, with improvements in speed and effectiveness and a reduction in the maintenance required. Presently, CPR is primarily used for freight transport across Canada and to the United States, as are many of the remaining railway systems. In 1977, the Federal Government, led by Prime Minister Trudeau, created Via Rail solely for passenger traffic. Since the advent of motor vehicles and the development of urban and inter-city transit systems, the demand for rail by passengers decreased and CN and CP underwent large economic losses. Via Rail was created to develop a system to be used solely to meet the demands of the public. Presently, Via Rail services are continually improving to meet passenger demands. For example, in 2006 internet access was made available to all passengers in class I and comfort classes (Via Rail Canada, 2007). For many Canadians, travel by train continues to be a more economical and convenient choice. However, rail transport is still highly dependent on trade and transport of freight across Canada, to the United States and to ports for international trade.

The history of Canadian railways is full of ups and downs: reduced passenger demands and funding shortages, which have been the main causes of decline from the more prosperous-earlier years. However, the economic and social benefits that railways have brought to Canadians are far greater than any of the "downs" experienced. Not only did extensive railway systems open doors for travel and settlement across the country in areas other than along the waterfronts, they provided access to many of the country's natural resources and other areas where Canadians were able to develop new markets (e.g., agriculture in Western Canada). Consequently, employment and economic development soared, and the railroad industry itself grew as a prominent market (Marsh, 2007). Adoption of railways as new travel modes had an impact on urban planning, particularly influencing the location of new industries, tourist amenities, and links to water and other transport modes.

The early history of rail transportation in Canada shows the large impact of the railways in initiating construction of other transportation infrastructure in Canada. The railways brought the need for other engineering projects such as bridges and tunnels (Marsh, 2007). In addition, railroads have also had an influential role in developing streetcars as urban transportation systems, such as the one presently used in Toronto, Ontario.

2.2.2. ***Roads, Bridges and Highway Networks***

After World War II, construction of more elaborate road networks was necessary to link Canadian cities. Millions of immigrants had settled in Canada and the number of families purchasing cars was increasing continually. The number of registered automobile users soared from 2,131 in 1907 to more than

50,000 in 1914, to approximately 1.62 million in 1930. However, even with these increasing numbers, the Great Depression and the two World Wars put a halt to road and highway construction. Additionally, most of the few paved roads that were created for military purposes were destroyed by heavy traffic during the war (Gilchrist, 2007). During the 1950's, rail remained the primary source of transportation across the country, but much was being done to increase the number of paved road networks to satisfy the automobile users (Trans-Canada Highway, 2007). The expenditures by local governments on road and highway construction increased from $103.5 million in 1946 to $1.5 billion in 1966, to $4.5 billion in 1986. Consequently, the number of paved urban roads and paved rural highways increased tremendously between 1946 and 1966, from 10,000 km to 49,662 km and from 28,982 km to 99,325 km, respectively (Gilchrist, 2007).

Road and highway expenditures increased significantly between 1946 and 1986, although they saw peak and declining periods during the 1990's, when expenditures ranged between $5.9 billion and $6.6 billion. The provincial and territorial expenditures were consistent with those of local governments during the same period (Gilchrist, 2007). The length of paved roads also soared in the years following WWII, although presently, the largest increase in road construction is with unpaved roads, around new rural developments and in the areas of resource recovery. As construction of unpaved roads is relatively inexpensive, they are used in areas with lower traffic. On the other hand, roads paved with hot mix asphalt, or concrete are constructed to handle regular traffic and to support heavy traffic loads at faster speeds. Table 2.1 summarizes the total length and percentage of public roads per province in 2006, along with the length and percentage of roads that are paved and unpaved. The road lengths are expressed in two-lane equivalent kilometres, where a lane-kilometre measures the number of lanes within the one-kilometre of road being considered.

Table 2.1 Length of paved, unpaved and total length and percentage distribution of public roads per province and territories in 2006 (Transport Canada, July 16 2007).

	Length (two-lane equivalent thousand km)			***Provinces, Territories share of total (per cent)***	***Percentage distribution***	
	Paved	***Unpaved***	***Total***		***Paved***	***Unpaved***
Newfoundland and Labrador	10.6	8.6	19.3	1.8	55.2	44.8
Prince Edward Island	4.3	1.8	6.0	0.6	70.8	29.2
Nova Scotia	18.1	9.0	27.1	2.6	66.8	33.2
New Brunswick	19.5	12.0	31.5	3.0	61.9	38.1
Quebec	81.5	63.2	144.7	13.9	56.3	43.7
Ontario	119.8	71.1	191.0	18.3	62.8	37.2
Manitoba	19.3	67.3	86.6	8.3	22.3	77.7
Saskatchewan	29.5	198.7	228.2	21.9	12.9	87.1
Alberta	61.7	164.6	226.3	21.7	27.3	72.7
British Columbia	48.2	22.9	71.1	6.8	67.8	32.2
Yukon	2.2	3.5	5.8	0.6	38.5	61.5
Northwest Territories	0.9	3.6	4.5	0.4	19.2	80.8
Nunavut	-	0.3	0.3	0.0	0.0	100.0
	415.6	**626.7**	**1,042.3**	**100.0**	**39.9**	**60.1**

Table 2.1 confirms that the Prairie Provinces and Northern Territories have the largest percentages of unpaved roads, and that Saskatchewan, Alberta, Ontario and Quebec have the largest share of public roads, which account for 75% of the total road network in Canada. These same provinces hold the largest share of

highways in the country, with the exception of British Columbia, which has the longest total highway system.

The highway system links Canada's major cities, provinces, and provides access to remote areas of the North and international border crossings. However, less than 60 years ago, the thought of linking the provinces by a highway system was a mere idea – an idea that, once made reality, gave way to elaborate highway construction in Canada and changed the course of transportation history.

In 1949, the Trans-Canada Highway Act was signed with the objective of connecting the provinces and major cities with a highway network. Completed in 1970, the 7,821 km Trans-Canada Highway is the world's longest national highway (CBC, June 5 2007). Extending from Victoria, B.C. to St. John's, NF, the highway improved tourism, national and international trade and has brought a sense of national unity to the country. The Trans-Canada Highway is substantial to the history of transport in Canada and is a significant part of the 38,000 km National Highway System. Table 2.2 shows the breakdown of the highway system by province and route type (i.e., core, feeder, Northern or remote route). The National Highway System accounts for less than 3% of the national road network, yet it supports most commercial trade and passenger travel across the provinces, or more than one-quarter of highway travel (WESTAC, 2007).

Table 2.2 Breakdown of the National Highway System by province and route type (core, feeder, northern and remote routes) (Transport Canada, July 16, 2007).

Jurisdiction	*Core Routes*	*Feeder Routes*	*Northern and Remote Routes*	*Total*
Yukon	1,079 km	-	948 km	2,027 km
Northwest Territories	576 km	-	847 km	1,423 km
Nunavut	-	-	-	-
British Columbia	5,861 km	447 km	724 km	7,032 km
Alberta	3,970 km	217 km	197 km	4,384 km
Saskatchewan	2,450 km	-	238 km	2,688 km
Manitoba	982 km	742 km	370 km	2,093 km
Ontario	6,131 km	706 km	-	6,836 km
Quebec	3,448 km	766 km	1,436 km	5,649 km
New Brunswick	993 km	832 km	-	1,825 km
Prince Edward Island	208 km	188 km	-	396 km
Nova Scotia	903 km	296 km	-	1,199 km
Newfoundland and Labrador	1,008 km	298 km	1,163 km	2,469 km
Total	**27,608 km**	**4,490 km**	**5,922 km**	**38,021 km**

The construction of bridges to support vehicular, rail and pedestrian traffic has enabled travel across many of Canada's waterways. Prior to bridge construction, streams or other smaller waterways were crossed with the use of trails made using wood logs. During the winter months, the ice provided sufficient support for people, however, during thawing and initial freezing periods, there was considerable hesitation to travel across the thinner ice. Bridge building was extensive in the post-war period. The first types of bridges seen in Canada were covered bridges and were found particularly in Quebec and New Brunswick. These were also termed “kissing bridges” because young lovers took advantage of the privacy of the covered bridges to steal a kiss. Some of the original covered bridges can still be found in both provinces, but mainly in New Brunswick, which is the home of the Hartland Bridge - the longest covered bridge in the world. Covered bridges were made of timber and had various simple truss designs. Engineers began using truss designs in the early 1800’s. Although wooden trusses were primarily used in the earlier years, steel took over as the leading material in bridge design by the end of the century. In the interim period, other materials were used, such as in the case of the Intercolonial Railroad built in 1876, partly supported on a bridge having masonry piers and wrought iron spans (Legget, 2007).

Reinforced concrete was adopted for construction of bridges in the early 1900’s. Presently, it remains the material of choice for highways, but some of the new larger bridges, made of structural concrete (Legget, 2007). For example, the 12.9 km, two-lane Confederation Bridge, linking New Brunswick and PEI and completed in 1997, is the longest bridge in the world to cross ice-covered salt water and is the longest bridge in North America. Needing 12 minutes to cross by car, this bridge has provided an environmentally-friendly and time-efficient alternative to the prior three hour ferry service. While many new designs and materials have been used since the beginning of bridge construction in Canada, the bridge failures discussed in *Chapter 1* suggest that experimentation with maintenance and monitoring techniques has been less extensive. Again, the Confederation Bridge shows the possibilities of applying new technologies to our bridges. Over 750 sensors were included in the bridge components to monitor the forces, deformations, temperature variations, and vibrations caused by traffic and seismic activity, and the sensors in the bridge’s piers being used to monitor the impacts of ice (Downey, 1998). Therefore, technological advances in bridge construction, inspection and monitoring are available – it is the application of these technologies and improvements in management that require progress and innovation.

2.2.3. ***Airfields***

Similar to the construction of roads to cater to the rapid increase in car users, airfields were needed following mass production of war aircrafts. Therefore, as was the case for roads and highways, the first airfields were also constructed for military purposes. The first powered aircrafts acquired in the United States were for military purposes in the early 1900s. After WWI, the Canadian government also sensed the need for acquiring military aviation, an acquisition which had already taken place in most industrialized nations. As a result, construction of airfields became extensive in Canada after the Royal Canadian Air Force was established in 1924 (National Defence, 2007).

In 1937, passenger flights began on the new government-owned Trans-Canada Airlines (TCA), the first flight being from Vancouver, B.C. to Seattle, Washington (CBC, 1939). In 1942, Canadian Pacific Air Lines (CP) was founded, covering Northern routes and therefore requiring the construction of new terminals and airfields in Northern areas. Passenger flights from Canada doubled from the end of the war in 1945 to 1948, then tripled by 1950. As with the first locomotives and first forms of transit, airplanes were far from perfect and being safe; they were noisy, not fully protected from aggressive weather conditions and were not equipped with emergency oxygen for passengers and staff (Watson, 1976). Conditions changed as technologies improved, air routes were altered and flight demand continued to grow.

The Trans-Canada Airlines became Air Canada in 1965, on a move by former Prime Minister Jean Chrétien for a bilingual name that also reflected the overseas routes covered by the airline. Although CP still provided service, this was limited to domestic flights at considerably lower frequencies than travel provided by Air Canada. Other smaller airlines emerged, some of them (including CP) joining together in 1987 to form Canadian Airlines, which until 2001 was Canada's second largest airline company. Today, the National Airports System

(NAS) includes 26 major airports in Canada (although smaller ones exist), which are owned by the federal government and serve 94% of cargo and passenger traffic (Transport Canada, July 30 2007).

In 2006, there were 3,903,900 passengers entering Canada using air transport, from countries other than the United States, compared with the to the 486,700 and 126,100 passengers entering by land and water transport, respectively. These statistics demonstrate the importance of runways, airport facilities and other related infrastructures within Canada's transportation network. Only 4,175,600 travelers from the United States came to Canada by airplane in 2006, whereas 22,064,900 used land transportation. However, air transport in this case still accounts for the second most widely used transportation mode to and from the United States, followed by bus (1,069,600), boat (955,600), train (123,300) and other transportation modes (483,700) (Statistics Canada, 2007). These statistics do not include the total number of passengers using air transport for domestic travel, which is quite common, given the accessibility provided by the air travel to remote areas of the North and given the faster travel times, compared with other transportation modes such as rail or transportation by road.

The first airports served mostly as military bases and training camps. Even when passenger flights were introduced, the available facilities at the airport were minimal, including the basic multi-functional facilities and few runways. Today, the public area, which includes numerous restaurants and commercial vendors, the multi-level parking facility, which allows for short- and long-term parking, and the hotel, for passenger convenience have all become essential parts to airport infrastructure as are the runways and terminal facilities. Just as is the case with ports, the air transportation infrastructure must ensure smooth, safe and efficient operation of airports and it extends far beyond the aviation authority's jurisdiction.

Figure 2.1 is a diagram illustrating the elaborate components of Montreal's Pierre-Elliott Trudeau International Airport, although many more exist including 52 gates, 71 self-service kiosks, 194 check-in desks and hangars and parking for as many as 72 aircrafts (Aéroports de Montréal, 2007). Figure 2.1 also shows the de-icing centre and the control tower, which are among the facilities needed to ensure adequate and safe operation of aircrafts, the parking center and search shelter, the customs office for safety measures, and the cargo buildings to handle large volumes of traded goods. Again, these facilities are among the countless others needed for proper functioning of airport operations. Additionally, easy access to major highways, sufficient taxi lanes, links to rapid transit and major metropolitan areas, and shuttle services have become vital to the competitiveness of Canada's major airports.

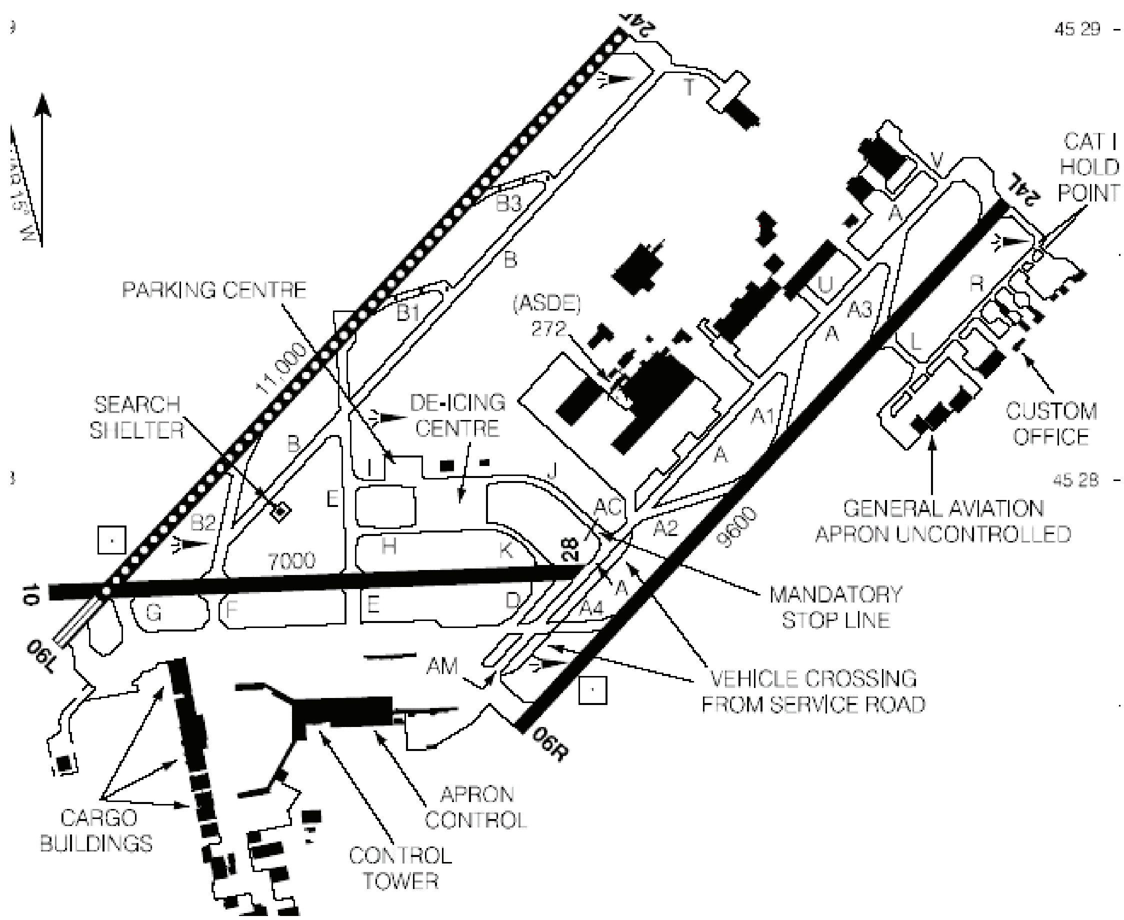

Figure 2.1 Facilities at Montreal's Pierre Elliott Trudeau International Airport (NAV Canada, 2007)

2.3 Transit Systems

Transit systems have evolved with the advent of new technologies. Electric power brought the electric railway and the trolley, and motors, and subsequently motor vehicles led to the creation of buses. The motives for the development of the first horse-drawn trams are quite similar to those for the present rapid-transit systems. Transit systems were developed as populations continued to grow, and suburban and industrial/commercial sectors were formed. Citizens needed to travel longer distances to get to work. Although speed, comfort and convenience are more significant in the present urban transportation planning, the current forms of public transportation have all evolved with the objective of providing the citizens with safe and efficient ways of traveling to and from their homes. Increased mobility of workers has resulted in the current economic prosperity and higher standards of living in countries with highly developed transportation networks.

*2.3.1. **The Beginning of Transit in Canada***

Toronto (1845) and Montreal (1860) were the first major cities to adopt the horse-drawn tram - the first form of urban transit in Canada. Horses were expensive, dirtied the streets, needed periods of rest and could not carry high loads. The electric streetcar, or tram, replaced the horse-drawn trams in the 1880's. The first electric street railway line was constructed in Windsor, Ontario. Trolleybuses, introduced in 1922, ran on rubber tires and derived energy from overhead power lines, thereby combining the benefits of electric streetcars and buses, which came into use in the 1920's (Day, 2007). Due to their lower cost and more flexible routing, buses continued to replace many streetcars, which were gradually phased out. Presently, Toronto has the largest streetcar system remaining in North America. Many citizens opposed the idea of abandoning this form of transit, therefore it was retained, maintained and modernized; streetcars were replaced and some routes were abandoned and relocated to reserved lanes.

Prince Edward Island similarly continues to benefit from seven trolley routes in addition to its bus service.

2.3.2. ***The Post-War Period***

In the case of other Canadian cities, most systems, such as trolleys and streetcars, were abandoned during the Great Depression and the Second World War; the needed major upgrades followed during the subsequent years. With the boom in urban development after this inactive period, increased and innovative forms of public transit were needed to satisfy the needs of the growing population, to prevent congestion and to encourage national growth. The world's first subway system was constructed in 1863 in London, England, which proved to be an effective way of reducing congestion. The first North American city to adopt its own subway system was Boston in 1898, but many years passed before a Canadian city turned to this form of transport – partly due to the municipal debt carried by many cities after the Great Depression, and the two world wars.

Toronto was the first Canadian city to adopt a subway line; the 7.4 km Toronto Yonge subway line was built between 1949 and 1954. The success of the subway was reflected in the crowds it brought to Downtown Toronto and the resulting boom in construction in the midtown and downtown areas. Subsequently, the subway line was expanded almost ten years later, in 1963 (CBC, July 15 2007). New lines and subway stations were constructed during the following years and other Canadian cities modeled Toronto and began adopting subway systems of their own. The next city to construct a subway was Montreal. Three subway lines were constructed (two in 1966 and one in 1967) totaling 22 km. The Montreal metro system consisted of rubber tires on concrete tracks, with the steel wheels and steel rails coming into operation when the rubber tires failed. Moscow and Mexico City have similar subway systems. Rubber tires provide a quieter, faster system as opposed to the traditional steel wheels on steel rails. They also required that the subway line be constructed entirely underground, unexposed to Montreal's harsh winter climate (CBC, July 15 2007).

2.3.3. *Modern Systems*

Rapid-transit systems now complement bus routes, commuter rail services and other transit systems in four other major Canadian cities. Edmonton was the first North American city with a population less than one million to build a modern Light Rail Transit system (LRT) in 1978 (ETS, 2007). The Edmonton Transit System's Light Rail Transit is 12.3 km long and comprises 11 stations, partly underground and partly at the street level. Calgary's C-Train (42.1 km – 36 stations – in operation since 1981) is a two line rapid transit system that runs partly underground and partly aboveground, and is powered by overhead electric wires. The Vancouver SkyTrain (49.5 km – 33 stations – 1986), the world's longest automated light rapid transit system, similarly runs on two lines, but on elevated tracks reserved specifically for transit, separated from the city traffic. Construction of the third line began in 2005 and plans for a fourth line are currently in progress. The newest but shortest system, the Ottawa O-Train (8 km – 5 stations – 2001), is a diesel powered light rail line, isolated from urban traffic, and shared with a Canadian Pacific freight rail line.

Rapid transit (RT) and light rail systems (LR) were solutions to providing faster and more frequent service by diverting traffic away from the busy streets. In many cities, buses have also been isolated from streets to their own designated right-of-way on highways and bridges, or simply reserved bus lanes, providing rapid bus service. Bus rapid transit (BRT) serves citizens in Calgary, Toronto, Montreal, Vancouver, York Region (Ontario), Edmonton, and Ottawa, which has one of the largest BRT routes in North America – the Transitway. In combination with modern RT and LR systems, cities now rely on more frequent, faster and more reliable modes of transportation that are continually being adapted to fulfill the increasing community needs. As the needs of different communities differ due to their geography, climate, population and lifestyles, the transit systems in different Canadian cities differ from one another to cater to the specific needs.

2.3.4. ***Improved Passenger Options***

Benefiting from its natural waterfront, Vancouver has provided the citizens with the option of the Seabus to commute from the North shore to Downtown Vancouver. This catamaran ferry transports passengers from a northern bus route terminal to the downtown area where more transit options are available, namely other bus routes, the Vancouver SkyTrain and the West Coast Express – a commuter train service. Halifax, because of it geography, has also adopted a daily passenger-harbor ferry service.

Canada's major cities which do not have RT, LR or ferry services, continue to use buses as the principal form of transit in busy areas. Yellowknife and Whitehorse provide bus routes on their principal streets. St. John's provides a Metrobus service in Newfoundland and Labrador that consists of 19 bus routes around its metropolitan area. Larger cities such as Montreal and Quebec City also provide a Taxibus service, a bus service that transports people to areas further away from their metropolitan downtown areas, where construction of a regular bus route is not economically feasible. In addition to its regular bus services, Montreal, Quebec City and Fredericton are among the cities offering special door-to-door bus services for people with disabilities. Although these systems have convenienced the daily travel of many people, most regular buses are now being designed to include wheelchair ramps.

The buses have also undergone numerous advancements similar to those for the modern subway systems, with technological upgrading of the buses (i.e., wheelchair ramps, automatic door-sensors, etc.), wider service options (i.e., more frequent service, BRT, etc.) and development of the appropriate infrastructure (i.e., express bus lanes, high-grade routes for BRT, etc.). Without these newer widespread options, communities and particularly metropolitan areas could not have developed as they have over the past century. As long as faster, more efficient and safe transit systems continue to evolve, both residents and tourists will continue to be attracted to Canadian cities, leading to an increase in the standard of living and Canada's competitiveness.

2.4 Ports

Ports consists of infrastructure assets along the waterfront where ships and boats are berthed, loaded and unloaded, and where cargo and passengers transfer to and from different modes of transportation. Therefore, ports constitute an important part of the transportation system of a country. Ports have complemented railway and airplanes in enabling the transport of people and goods internationally, though transport by ship has primarily been the least expensive and, therefore, the preferred mode of transport for large shipments of goods (Heaver, 2007). The Canadian Port Authorities "handle approximately $100 billion worth of goods annually, a quarter of all Canadian trade" (ACPA, 2006), making ports vital points in Canada's transportation network.

A port comprises several wharves, terminals and piers and it must be equipped with the required technology for loading and unloading of vessels. However, the infrastructure required for the daily operations of a port extend far beyond that within a port's jurisdiction. Intermodal transport is necessary in ports where, depending on the port's location and the nature of its activities, railway stations, transit systems, ferry terminals, road networks, and bridges are necessary for both the transport of cargo and passengers to and from the port.

The Association of Canadian Port Authorities (ACPA) represents Canada's ports, harbors, and other port-related businesses and organizations. Founded in 1958, this national association is the common link between the latter groups, private sector companies, transportation associations, the government and the public. This association works to develop Canadian ports as economic engines and strives to increase public awareness and interest in all of their activities. Raising awareness of the deteriorated state of waterfront infrastructure and the changes needed to meet the various port needs is the responsibility of the ACPA.

2.4.1. ***Canada's Waterways and the Beginnings of Trade***

The waters surrounding most of Canada have been an advantage commercially throughout Canadian history; these three oceans also represent an added threat to the country from possible invasions, terrorist attacks, and other forms of criminal activity. For this reason, port infrastructure now includes some the most widespread technologies and security systems. The large amounts of cargo handled in Canadian Ports, advancements in cargo handling and storage equipment ensure sustained effectiveness of port operations, and in turn, competitiveness among the other major world ports. However, much of Canada's success on the international market is mainly due to its geographical position; its waterways have enabled trade since the very beginning of Canadian history.

The first settlers traveled to the interior of Canada via the St. Lawrence River, which served as the primary maritime route for travel, war ships and transport of goods, particularly for trading of fur which began in the 1600's and continued to be a major industry until the mid 1800's. The first signs of engineering along the St. Lawrence date back to the 1680's, with the construction of the first canal around the Lachine Rapids. Until the 1800's other canals were constructed along other rapids, and dredging and channeling was performed to allow the passage of more boats. The St. Lawrence Seaway officially opened to oceangoing shipping in 1959; its improved channels provide uninterrupted access to the Great Lakes by larger vessels (Owens, 2007).

Iron, wood and fur were important industries by the early 1800's and although their manufacturing and trade was extensive, little port facilities had been constructed by that time. The terminals, wharves, docks and piers used today were non-existent, leaving ship owners no choice but to anchor their boats in the open-sea. Being distant from the shore, freight and passengers had to be transported from these anchored boats to shore with the use of other boats, or ferries. Presently, the waterfront infrastructure listed above not only enable the direct transfer of passengers and cargo on land, but are equipped with fender systems and the cargo-carrying equipment necessary for quick and efficient handling of goods. The construction of docks began in 1818, when a dock and hangar (the first port facilities) were constructed in Trois-Rivières, between Montreal and Quebec. By 1935, 2743.3 meters of wharves were constructed (Port of Trois-Rivières, 2007) and have since increased to meet the increasing trade demands.

The technological developments following the Second World War led to the abandonment of the deteriorated infrastructure in many ports. Many cruise ship terminals and piers lost their usefulness as travel by plane became common. Development of the post World War II transportation infrastructure involved construction of many bridges, highways and road networks, resulting in the increase in the number of family cars, which led to a reduced need for ferry terminals at the ports. Furthermore, many railroad networks were abandoned due to increases in truck delivery to and from ports (Breen and Rigby, 1994). The need for revitalization of many ports and waterfronts arose during the 1950's and 1960's. The increase in the size of ships and in the amounts of imports and exports, the emergence of new machinery and the development of new transportation networks had a tremendous impact on port operations and redevelopment needs.

2.4.2. ***Increased Environmental Concerns***

Beginning in the 1970's, the image of many ports changed due to greater environmental awareness. Many waterfronts were designed by planners to embrace some of the natural splendors found on coasts around the world. Increased governmental concern and therefore, spending on cleaning up waters and creating environmental codes and regulations transformed the image of many ports. While people were once turned away from the more "industrialized" looking waterfronts, they are now being drawn towards the natural waters, landscapes and vegetation found in the waterfront environments (Breen and Rigby, 1994). Therefore, port facilities have gone beyond the containers and storage facilities that meet the commercial demands, but they now include many public and recreational facilities to meet recreational and tourism demands. Furthermore, the diversity of the ecosystem found in ports, where activities and operations are endless, demonstrates the importance of the environmental considerations needed in such locations, which has led to the development of more sustainable and environmentally-friendly machinery and practices over the years.

2.4.3. ***The Canadian Port Authorities***

In 1998, the Canadian Government adopted the *Canada Marine Act* (CMA) to set standard practices for all Canadian ports. Many of these practices were developed based on international policies, and therefore, they were aimed at promoting and increasing the competitiveness of Canada's ports. The CMA was aimed at regulating infrastructure management, environmental policies, services offered and their costs, safety procedures, transportation systems and other port activities within the different jurisdictions. Implementation of the CMA led to the creation of the 19 Canadian Port Authorities (CPA), which administer each port based on the governing procedures outlined in the CMA. Therefore, the Port Authorities operate under federal jurisdiction and were created as another means of controlling port governance and regulating port operations across the country. Presently, the CPA not only handle a significant portion of the traded goods, but create over 250,000 direct and indirect jobs: overall the economic impact of the CPA activities surpasses $20 billion annually (ACPA, 2006).

Modernization of waterfront infrastructure due to new technologies is necessary if ports are to remain competitive in the international market. Foreign trade and domestic cargo are expected to double or even triple by 2020 (ACPA, 2004). Canada, the United States and Mexico initiated the North American Free Trade Agreement in January 1994. Since then, trade between Canada and the United States has doubled. Trade with countries such as China, India and South Korea are also expected to double over the next 15 years (ACPA, 2006). These increases in trade, the continuous development of new technologies and the increasing demands of markets where commercial activity is high, are all exerting considerable pressure on ports. If the ports are to remain competitive and continue to contribute to improving the quality of life in Canadian communities, significant upgrades will be needed in the future.

2.5 Water Supply and Sewage Disposal Systems

Prior to the development of municipal water distribution systems, people collected water for their own use from local wells, or other nearby water sources. In some areas of British Columbia, dogs were used to distribute water to households (James, 1998). The disposal of untreated wastewater and industrial wastes into the same nearby bodies of water was the norm. However, with greater knowledge of waterborne diseases, disease transmission and fire safety came a public demand for urban water supply and sewage disposal systems. By the beginning of the 1900's, most developed communities in Canada had a water distribution system, which along with the subsequent construction of sewage systems, improved public health tremendously. Throughout the 1900's, water and sewer systems were enlarged and extended to meet new needs required by the population growth in new and existing developments. Water and sewer systems, along with the advent of water treatment technologies, improved water quality chemically and aesthetically, thereby reducing health and environmental risks.

As with other types of infrastructure, the materials and practices used in the construction of underground and other associated infrastructure assets (e.g., treatment plants) have improved considerably because of several related innovations. The different infrastructure categories have a common role in impacting the quality of life of all citizens. Of all the infrastructure categories, however, underground infrastructure has had the greatest impact on public health and the environment. The shift from the earlier to modern water distribution and sewage disposal systems will be considered separately, highlighting these impacts. A short note on the evolution of storm water collection and water treatment is also included for completeness.

2.5.1. ***Water Distribution***

The records show that the first privately owned water systems existed in Montreal, as early as 1801. The first public water system in Canada was built in Saint John, New Brunswick in 1837. Toronto (1841), Montreal (1845), and

Halifax (1848) followed suit immediately afterwards. In the early 1900's, water supply systems existed in all major Canadian cities. The development of water distribution systems in smaller communities followed the improvement of pipe construction and the use of new pipe materials, which considerably reduced construction, repair and maintenance costs for these smaller communities (Infrastructure Canada, July 2 2007).

Initially, wood was the primary pipe material, while clay and grey cast iron (GCI) were also used. By the early 1900's, concrete, vitrified clay and asbestos cement pipes, and pipes made of cellulose fiber, impregnated with coal-tar pitch, were being employed increasingly for water distribution. Sewer systems, which were constructed within the same timeframe, were also primarily made of wood, though larger conduits were made of brick, stone or slate. In the late 1800's and early 1900's, vitrified clay and cement mortar were generally used for smaller sewers, and cast iron and concrete were utilized for constructing larger conduits (Shladweiler, 2007). Polyvinyl chloride (PVC) and other composite pipes emerged in the 1960's, followed by the use of ductile cast iron (DCI) in the 1970's. Table 2.3 summarizes the total length and the percentage of pipe material still in use today, based on a study of 21 municipalities across Canada. It should be noted that pipes made of other materials, such as wood and ceramic, are still found in some older districts.

Table 2.3 Length and percentage of pipe materials in use today (Rajani and McDonald , 1995).

Pipe Type	**GCI**	**DCI**	**AC**	**PVC**	**PCCP (Prestressed concrete cyclindrical pipe)**	**Total**
Total length km/pipe type	8,769	4,238	2,105	1,818	623	17,554
Percentage of total length	50.0%	24.1%	12.0%	10.4%	3.6%	100%

About 75% of the existing water pipes in Canada are made of grey- and ductile cast iron (50% made of grey-cast iron which was one of the earlier materials employed). Although presently, pipes made of asbestos cement (AC) are rarely fabricated, 12% of the pipes made from asbestos cement are still in use, which has caused considerable public concern. Asbestos is considered carcinogenic if inhaled, however, no significant health risks have been attributed to the ingestion of water passing through this type of pipe (Walski, 2006). It is also interesting to note that the use of polyvinyl chloride (PVC) pipes, which were introduced for water and sewage systems in the 1960's, has surpassed the use of prestressed concrete, which has been used since the beginning the 1930's (Portland Cement Association, 2008).

Construction practices and design methods have also changed considerably. The PVC pipes have facilitated construction tremendously, because they are lightweight and easy to install. This material is, therefore, just one of the many that have resulted in improvements in the public works sector over the past century. When watching a road reconstruction project today, while surrounded by heavy trucks, it is difficult to imagine that trenches were once dug by hand. Also, through trial and error and with the emergence of prefabricated pipes, circular cross-sectional pipes were adopted by engineers to replace the original rectangular cross-sections, diminishing sedimentation and improving flow pressures. Like bridges, new construction methods (e.g., trenchless technologies) and monitoring technologies (e.g., watermeters) emerged over the past century. While these have been accepted and deemed successful in some communities, they have yet to gain wider acceptance in many others.

Other water supply infrastructure besides the obvious watermains and smaller distribution pipes are pressure reducing stations, watermeters, storage capacity (i.e., reservoirs), pumping stations and watertreatment plants.

2.5.2. ***Sanitary Sewers***

Prior to the advent of urban sanitary sewage systems, human and other wastes were accumulated in buckets and dumped outside the home, in the street, or in nearby bodies of water. Waste collection commenced in 1760, when the government ordered residents to accumulate their waste on the front of their properties, where it would be picked up and dumped into the St. Lawrence River. Using a bucket instead of a flush toilet - the honey bucket system – remained the norm in many Arctic communities. In other parts of Canada, where plagues of cholera and typhoid were becoming increasingly common, the way communities dealt with wastes needed reconsideration.

The first sewage systems were constructed between 1830 and 1860, in Toronto, York and Hamilton (James, 1998). At the time, not much importance was placed on sealing the pipe joints. Engineers felt that if groundwater penetrated the joint it would improve sewage flow, while simultaneously acting as a drain to collect the rainwater. The opposite scenario was of no concern: sewage penetrating the joints into the groundwater was not perceived as being harmful (Shladweiler, 2007). Presently, ensuring proper sealing of joints is an essential requirement, as leaks pose a serious risk for contamination of the groundwater, which is relied on by 30.3% of the population in Canada (9 million Canadians) and 90% of Canadian farms (Environment Canada, 2006). However, cracks and leaking joints are also cause for concern where groundwater is not of reliable quality for domestic use. The contaminated groundwater, or soil may make its way to the nearby water pipe, which, if cracked, or if not sealed properly, will allow these contaminants to ingress. Sealing methods and leak detection techniques have improved significantly over the decades to avoid such occurrences.

2.5.3. ***Stormwater Collection***

In the mid-1950's, engineers began designing separate sewage systems. Such systems consist of two conduits; one for sanitary sewage (i.e., waste from homes, industries and other facilites) and the other for stormwater (i.e., rainwater, snow melt and other surface water from watering lawns, etc.). A sewer carrying municipal wastewater (a combination of both sanitary sewage and stormwater) is called a combined sewer and can still be found in areas with older systems. As many of these communities also have older treatment facilities, there remains a risk of overloading the facility during periods of heavy rainfall, at which point raw sewage may overflow into a body of clean water prior to being treated. The development of separate sewers has prevented this risk and has also avoided the unnecessary costs of treating stormwater at levels similar to those of sanitary sewage (Environment Canada et al, 2001).

Both combined and stormwater sewers consist of more than just pipes, and include infrastructure, such as interceptors, manholes, retention basins, septic tanks, lift stations and treatment plants (including all associated facilities and equipment) which will be discussed next.

2.5.4. *Treatment Plants*

The link between exposure to human wastes and the transmission of certain diseases, particularly typhoid, was made by European scientists in the 1880's (The Municipality of Metropolitan Toronto, 1997). These new discoveries led to the construction of sewer systems and treatment plants, which not only reduced foul odours, but reduced the death toll caused by the infectious diseases of the 19th century.

A slow-sand filtration plant was established in Toronto in 1912, after George Whipple, a Harvard engineering consultant, suggested that water should be filtered as opposed to the more costly option of purifying sewage. Between 1914 and 1918 a faster drifting-sand filtration system replaced the first filtration plant and was the largest of its kind. The treatment consisted of adding a liquid coagulant to remove bacteria, followed by filtration of the water through sand-filled iron cylinders, and finally the addition of liquid chlorine (The Municipality of Metropolitan Toronto, 1997). Water purification quickly reduced the death rate caused by typhoid and cholera, though the public was not fully satisfied with the new treatment systems. The citizens did not like the taste of chlorinated water, and many were bothered by the fact that their drinking water was chemically modified – a concern that seems unreasonable because of the prior exposure of water to sewage.

The sewage treatment underwent many changes in following years, particularly after the 1950's, with a considerable increase in the environmental concerns. The fish deaths due to chemical contamination and dissolved oxygen depletion, algal bloom from high nutrient levels and the destruction of natural habitats are among the impacts of wastewater. Along with the continuing goal of reducing risks to human health, treatment was improved to reduce these environmental impacts. Improvements varied for different communities and the level and sequencing of treatment continued to vary for different treatment plants across Canada, according to the needs of different communities. Most of the large treatment facilities adopt the activated sludge system, which uses microorganisms (encouraged to grow within the secondary treatment tanks) to help remove suspended solids after the primary treatment, and facilitate their settlement. Following this procedure, liquid chlorine is added to kill the remaining bacteria. Reducing the suspended solids in sewage plant effluent has improved treatment quality and has greatly reduced negative impacts on the ecosystem. Even with the recent significant improvements, problems persist with the adequacy of the treatment methods.

Inadequate treatment may occur as a result of an aging infrastructure. Furthermore, new treatment processes need to be devised to counteract the problem of certain chemicals not being effectively eliminated. Some substances, such as pesticides, industrial chemicals, certain detergents, natural estrogen and other hormones from human wastes can pass through the wastewater treatment system, disrupting the growth, reproduction and development of many species. These substances are known as endocrine disruptors, and have been found to cause feminization of male fish and deformities in many fish and bird species, among other "disruptions".

Not much is known about the extent of this problem in Canada, although there is evidence of animal life being affected negatively by these chemicals. Endocrine-disrupting chemicals may affect the immune system, the brain, the thyroid gland, the nervous system, sexual development and reproduction. With evidence of animal life being affected by these chemicals, much has to be done to eliminate these effects on wildlife and prevent the negative effects of these chemicals on humans who consume both the fish and the water. There is considerable focus on research in this area, yet no immediate solutions have been devised for improving treatment methods, or controlling the input of these chemicals in wastewater.

The variability of treatment methods and treatment facilities pose an additional complication to counteracting this problem. In 1999, approximately 26% of Canadians (mainly in rural areas) relied on septic tanks for sewage treatment. Out of the 74% of the population serviced by sewage systems, 97% relied on sewage treatment of varying levels (Environment Canada et al, 2001). Of those benefiting from sewage treatment, 78% were benefiting from at least secondary or tertiary treatment. Activated sewage sludge systems have greatly increased from 1983, when 56% of the population with sewage disposal systems, was benefiting from at least secondary treatment. Treatment levels have increased, yet the previous numbers also show that 3% of the population continue to dispose of wastes in nearby bodies of water.

CHAPTER 3

INFRASTRUCTURE: THE PRESENT SITUATION

3.1 Infrastructure Surveys

The infrastructure deficit is the difference between the funding that is needed and the available funding to maintain and upgrade existing municipal infrastructure systems. Presently, the infrastructure deficit for a country such as Canada at a given time is established by an appropriately designed survey of the various member communities, such as the municipalities, or other organizations owning infrastructure. Figure 3.1, shows the deficits for Canada's municipal infrastructure obtained from previous surveys up to 2003. As can be seen, the deficit has compounded from one study to the next due to a number of factors. Deferred maintenance has led to extremely rapid deterioration of the infrastructure, aging being another factor causing the deficit to escalate. Other factors include demographics, geography, local needs, climate change and economics.

Larger communities place higher demands on transportation and transit systems than smaller rural and northern communities, showing how demographics can affect the infrastructure deficit. Northern and coastal communities have varying needs than larger inland cities, demonstrating the effects of geography. Local needs will clearly vary from one region to another, based on a community's activities, climate, population, socio-economic conditions, etc. Climate change will also place heavy strains on the effective performance of the existing infrastructure; economic factors such as inflation will also have a negative impact on the deficit (Mirza, 2007). Each of the factors discussed should be considered for a more scientific estimate of the infrastructure deficit. A literature review of the past studies showed that the latter factors were not considered when devising past deficit estimates. Efforts were made to include these in the 2007 FCM-McGill Survey.

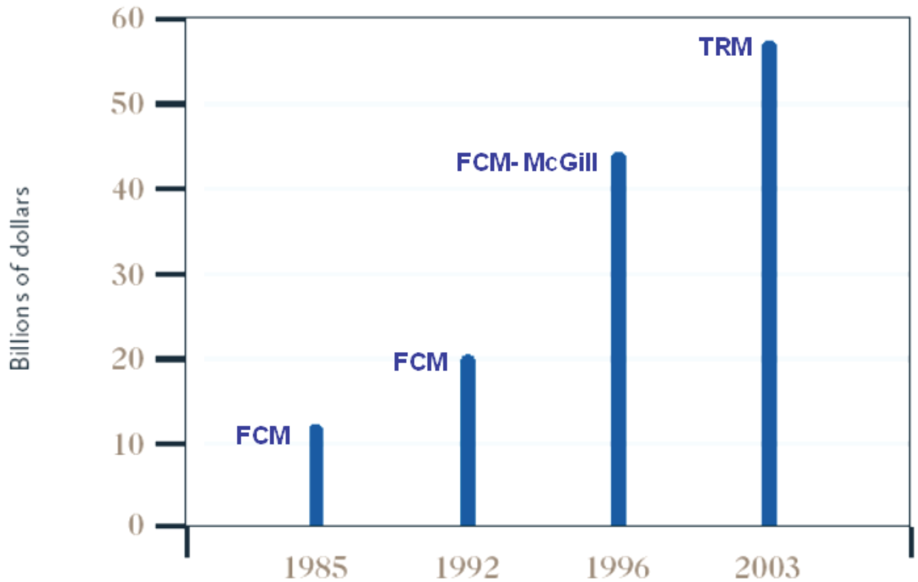

Figure 3.1 Canada's infrastructure deficits devised from studies between 1985 and 2003 (Mirza, 2007).

*3.1.1. **The 2007 FCM-McGill Municipal Infrastructure Survey***

Following a literature review of the past surveys, a draft questionnaire was formulated with consideration for the main infrastructure categories that were considered in past surveys to enable comparative analysis. Where applicable, each main infrastructure category was further subdivided into sub-categories to gain more detailed information about specific infrastructure assets, making this survey the most comprehensive of its kind. The draft survey was distributed in both English and French to professionals across Canada, dealing with different aspects of infrastructure (i.e., finance, engineering, etc.). Feedback from these professionals enabled amelioration of the survey questionnaire prior to its final distribution to 166 municipalities across Canada in October 2007. These municipalities were asked to respond to six broad questions through an online survey software, email or fax, within a period of one month. The six questions dealt primarily with the municipality's current budgeting practices (e.g., annual operating and capital expenditures), their existing and projected upgrading needs and their needs for new infrastructure. To account for varying local needs and the influences of other factors such as climate change and urban sprawl, municipalities were asked to rank the influence of these factors on compounding their municipal infrastructure deficits. These factors were also considered in careful selection of responding municipalities. Municipalities were selected from each province, territory and from population groups varying from greater than one million people to less than 10,000 people.

Complete and partial responses were received from 85 local governments, giving a total response rate of 51%, which is representative of 46% of the total national population. The Nunavut Association of Municipalities (NAM) responded on behalf of 24 local governments, giving a good representation of the needs of the northern communities. Table B.1 in *Appendix B* briefly highlights the objectives and other details of the 2007 survey and other previous surveys (e.g., response rates): the 1985 and 1992 FCM surveys, the *1996 FCM-McGill Infrastructure Survey* and the *2003 Technology Road Map*.

Responses to the second part of the *2007 FCM-McGill Municipal Infrastructure Survey* were returned one month after the first deadline. Questions in this second part dealt with the infrastructure stock of the municipalities: its inventory, average age and condition rating. An incomplete data set was returned from each of the municipalities who responded to the second half of the survey questionnaire. Where data was incomplete, most municipalities responded that "information is unavailable", showing that the available information about the country's infrastructure stock is limited or incomplete.

3.1.2. ***Other Infrastructure Surveys***

A smaller – less comprehensive survey was conducted by the NRC and another by *Municipal World*, a Canadian municipal magazine who worked in conjunction with *IPSOS/REID*, a market research company. The questions pertaining to the condition of infrastructure assets in the 2004 NRC survey - *Survey on Municipal Infrastructure Assets* – were not specific to different infrastructure categories but to the municipality's infrastructure stock and infrastructure-related management practices in general. It should also be noted that the 2006 *IPSOS/REID Municipal World Survey* was conducted by the general public and not by the municipalities. Table B.2 in *Appendix B* summarizes the details of both the NRC and the *Municipal World* surveys. The survey findings of both surveys were excluded from Table B.1 to enable more accurate comparisons of the state of the main infrastructure categories over the past 20 years, based solely on the data received from municipal officials and infrastructure professionals working for municipalities.

The results from the *IPSOS/REID Municipal World Survey* (see Section 4.1) show that although the public is aware that the infrastructure is in a poor state of health, their responses are more optimistic than the realities of the current infrastructure crisis. Though the response rate for the 2004 NRC survey was not high, the survey nevertheless demonstrated interesting results. In particular, the municipalities' confidence levels in the responses they submitted were low, further suggesting that many uncertainties exist regarding the state of infrastructure due to the lack of standardized condition assessment techniques and inventory keeping. The reported annual maintenance expenditures also proved to be below the required sustainable levels (see section Section 4.3).

3.2 The Present State of Canada's Infrastructure

The following sections will examine each of the main infrastructure categories included in the *2007 FCM-McGill Infrastructure Survey*. The present state of each category will be discussed and the survey findings will be summarized. First, Table 3.1 lists the infrastructure assets that are included in each category.

Table 3.1 Main infrastructure categories and sub-categories.

Water Supply Systems	▪ Watermains (trunkmains) ▪ Distribution pipes ▪ Pressure reducing stations ▪ Watermeters ▪ Treatment plants ▪ Storage capacity (including reservoirs) ▪ Pumping stations
Wastewater and Stormwater Systems	▪ Sewage pipes ▪ Storm water pipes ▪ Sewage interceptors ▪ Storm water interceptors ▪ Combined (sewage and storm water) pipes ▪ Combined (sewage and storm water) interceptors ▪ Manholes ▪ Treatment plants, including all associated facilities and equipment ▪ Retention basins ▪ Septic tanks ▪ Lift stations
Transportation	▪ Emergency vehicles ▪ Road cleaning and snow removing vehicles (snow plows, bulldozers, sidewalk snow removing vehicles) ▪ Road cleaning and snow removal - facilities ▪ Airports ▪ Airports- Annual traffic count (one traffic count includes one arrival and one departure) ▪ Ferries ▪ Docking facilities ▪ Paved roads ▪ Unpaved roads ▪ Sidewalks ▪ Curbs ▪ Bicycle paths ▪ Bridges
Transit Systems	▪ Rapid transit systems, light rail transit systems and subways – track, rolling stock, stations, service facilities and parking facilities ▪ Municipal parking areas ▪ Buses - dedicated lanes, rolling stock, stations, service facilities, parking facilities ▪ Trams – tracks, rolling stock, stations, service facilities, parking facilities
Cultural, Social, Community and Recreational	▪ Government buildings (including structures, parking facilities, etc.) ▪ Public buildings (community and social services, police, fire and paramedic stations, etc.) ▪ Multipurpose complexes (stadiums, theatres, opera and concert performance facilities, convention centres, etc.) ▪ Sports complexes - outdoor ▪ Municipal housing facilities ▪ Municipal parks ▪ Parks and playgrounds- playing areas, parking areas, picnic areas, pools

	▪ Lake and water sports facilities (beaches, marinas, picnic and parking areas) ▪ Municipally-owned theme parks, casinos
Waste Management	▪ Landfills ▪ Municipal recycling facilities ▪ Hazardous waste disposal/storage facilities ▪ Hazardous waste recycling facilities ▪ Municipal waste vehicles ▪ Hazardous waste vehicles

*3.2.1. **Water and Wastewater Systems***

In 2000, water and wastewater systems made up 30% of Canada's total municipal infrastructure stock (Tarek et al, 2003). The results of the *2007 FCM-McGill Infrastructure Survey* for the two main infrastructure categories were found to be consistent with the deficit estimates from more specialized groups. In 2003, for example, the Canadian Water Network estimated a deficit of $39 billion dollars to upgrade existing infrastructure in this area. They also estimated that between 2003 and 2013, $90 billion would be needed to meet upgrading and new needs. Similarly, the Canadian Water and Wastewater Association (CWWA) found that $88.5 billion were needed in 1997 over a period of 15 years for all needs (upgrading and new needs) in this area. According to the latest 2007 FCM-McGill study, the municipal infrastructure deficit to upgrade existing infrastructure is $31 billion, an increase of $10 billion since the 1996 survey. The deficit for new needs is $56.6 billion (Table 3.2). If the cost to upgrade existing infrastructure and the cost for new infrastructure needs are added together, the total $86.6 billion is consistent with the estimated $90 billion and $88.5 billion deficits estimated by the CWA and CWWA, respectively.

Table 3.2 The municipal infrastructure sub-deficit for water and wastewater systems, in 1996 and 2007.

	1996	**2007**
Average cost to upgrade* existing infrastructure assets	$21 billion	$31 billion
Average cost for new infrastructure needs**	-	$56.6 billion

*Upgrading - includes the maintenance, repair, rehabilitation, and replacement needed to bring existing infrastructure assets to acceptable levels of safety and serviceability.

**New needs - includes the infrastructure that is needed to meet the new needs generated by population growth, the environment, new laws and regulations, suburban sprawl, etc.

In 1999, the total length of water supply pipes in Canada was estimated at 112,297 km and that of wastewater pipe (sewage and stormwater combined) at 109,296 km (Felio, 1999). As mentioned, an accurate estimate of the total pipe length and condition of the underground infrastructure could not be deduced from the responses, as the information provided by the municipalities was limited. In 1996, the survey results showed that sanitary and combined sewers, water distribution systems, water supply systems and stormwater systems were the oldest infrastructure systems at the national level with an average age of 42, 37, 36 and 32 years, respectively. Additionally, municipalities with populations between 10,000 and 100,000 claimed that the condition of their sanitary and combined sewer systems was getting worse. The municipalities with populations between 10,000 and 100,000 (2007 survey) classified the condition of their water and wastewater systems (and their sub-categories) as being between the states of "acceptable" and "needs some repair". In 1996 municipalities with populations between 100,000 and 400,000 claimed that their water distribution systems were improving.

In 2007, the number of responses obtained from the 100,000 to 400,000 population group represented 13% of the group's total population. The responses showed that water supply systems in some cases were classified as "needs extensive repair". Since the 1996 survey, the $10 billion deficit increase also suggests that the condition of the water and wastewater systems has worsened at the national level. Table 3.3 summarizes the average condition ratings for the 100,000 to 400,000 population group for both the water supply, and wastewater and stormwater system categories. Responding municipalities classified the condition of their infrastructure assets according to the following scale:

- 1 – good
- 2 – acceptable
- 3 – needs some repair
- 4 – needs extensive repair
- 5 – not acceptable
- 6 – not under municipal jurisdiction, not existing, or not applicable

Table 3.3 Average condition ratings for water supply, and wastewater and stormwater systems in municipalities with populations between 100,000 to 400,000.

Water Supply Systems	Condition Rating	No. of Responses	Population Represented	% of Group
Water mains (trunkmains)	2.6	6	954,437	12.7
Distribution pipes	2.6	8	1,249,437	16.7
Pressure reducing stations	4	4	689,494	9.2
Water meters	1.7	6	924,494	12.3
Treatment plant(s)	3.4	4	728,757	9.7
Storage capacity (including all reservoirs)	3	5	839,494	11.2
Pumping stations	2.7	7	1,134,494	15.1
Wastewater and Stormwater Systems	**Condition Rating**	**No. of Responses**	**Population Represented**	**% of Group**
Sewage pipes	2.1	7	1,038,537	13.8
Sewage interceptors*	1.7	5	839,494	11.2
Storm water pipes	2.3	6	880,680	11.7
Storm water interceptors*	2.9	3	470,737	6.3
Combined (sewage and storm water) pipes	4.2	3	518,757	6.9
Combined (sewage and storm water) interceptors	4.8	2	360,900	4.8
Manholes	2.2	6	808,594	10.8
Treatment plants, including all associated facilities and equipment	3	2	307,857	4.1
Retention basins (×1,000 m^3)	1.9	5	765,737	10.2
Septic tanks	5.7	2	321,637	4.3
Lift stations	2.2	5	713,594	9.5

Results of the previous two (1996 and 2007) FCM-McGill surveys can be complemented by a national report card published by the Sierra Legal Defence Fund in 2006, which specifically analyzed the adequacy of water regulations in Canada. The letter grades assigned to the various provinces show that all but one province have improved their water protection, treatment and testing methods and have complied with new water safety regulations since the last report card was published in 2001 (Table 3.3), which shows that while the provinces and territories have improved in the area of drinking water, other improvements in operations, testing and standards, among others, have been recommended. In particular, the Sierra Legal Defence Fund has listed numerous recommendations and guidelines that the provincial, territorial and federal governments should adopt, including strict implementation of recommendations from the Walkerton Commission of Inquiry and improvement of the water quality standards in the First Nation Communities (Sierra Legal Defence Fund, 2006). The Sierra Legal Defence Fund has not limited their scope of work to the improvement of water quality, but to wastewater treatment as well.

In 1999, 74% of the Canadian population was serviced by a municipal sewer system; 97% of which were served by some level of sewage treatment. The other 26% not serviced by a municipal sewer system relied on septic tanks for sewage treatment (Environment Canada et al, 2001). Therefore, 3% of the population serviced by a sewer system are not serviced by some level of treatment, which is simply unacceptable. Water treatment is an infrastructure category which has made considerable progress since 2001. Cities such as Edmonton, Calgary and Whistler have progressed in recent years, treating all of their sewage with advanced tertiary levels of treatment (Sierra Legal Defence Fund, 2004). However, due to faulty infrastructure and little progress by other municipalities, in their treatment practices, further work is still needed.

The Sierra Legal Defence Fund also publishes a national report card, evaluating the sewage treatment in Canadian cities with letter grades from A to F. Table 3.4 compares the grades given to 22 cities in 1999 and 2004. Of the 22 cities, 14 have made some progress since the 1999 report, 3 cities have degraded and 4 have not changed their treatment methods – remaining in a similar situation as in 1999. The Sierra report clearly portrays the current shocking state of water treatment in some of Canada's major cities:

> *"Of the twenty-two cities documented in this report, five (Victoria, Saint John, Halifax, St. John's and Dawson City) continue to dump some or all of their sewage, raw and untreated directly into Canada's rivers, lakes and oceans – a total of 140 billion litres per year. Three other cities (Vancouver, Montreal, and Charlottetown) discharge some or all of their sewage after receiving only primary treatment, consisting of little more than the settling and skimming off of large debris. Together, these eight municipalities alone generate more than 3.0 billion litres of sewage effluent per day - nearly 40,000 litres every second. All of it is discharged with no, or only minimal, treatment"* (Sierra Legal Defence Fund, 2004).

The report also reveals that due to combined sewer overflows and treatment plant bypasses, another 42 billion litres of untreated sewage from our major cities are discharged into the environment every year. These cities include Montreal, Toronto, Vancouver, Edmonton and Hamilton (Sierra Legal Defence Fund, 2004). Table 3.5 shows that the city of Victoria, being the only Canadian city that still discharges all of its raw sewage into the environment, was suspended in 2004.

Table 3.4 National Water Report Card II (Sierra Legal Defence Fund, 2006).

NATIONAL DRINKING WATER REPORT CARD – GRADES			
Jurisdiction	**Comments (source protection comments not included)**	**2001**	**2006**
Alberta	GOOD: Treatment standards; contaminant standards; accredited labs for water quality testing; operator certification. NEEDS IMPROVEMENT: testing. LACKING: public reporting.	B	B
British Columbia	GOOD: accredited labs for water quality testing; operator certification. NEEDS IMPROVEMENT: treatment standards; contaminant standards; testing; public reporting.	D	C+
Manitoba	GOOD: accredited labs for water quality testing; operator certification; public reporting (planned). NEEDS IMPROVEMENT: treatment standards; contaminant standards; testing.	C-	C+
Newfoundland	GOOD: testing; government tests water quality; public reporting. NEEDS IMPROVEMENT: treatment standards; contaminant standards. LACKING: operator certification.	D	C-
New Brunswick	GOOD: accredited labs for water quality testing. NEEDS IMPROVEMENT: treatment standards; testing. LACKING: contaminant standards; water treatment system design regulation; operator certification; public reporting.	C-	D
NW Territories	GOOD: contaminant standards; testing; accredited labs for water quality testing; public reporting. NEEDS IMPROVEMENT: treatment standards. LACKING: operator certification.	C	C+
Nova Scotia	GOOD: treatment standards; contaminant standards; accredited labs for water quality testing; operator certification. LACKING: public reporting.	B-	B
Nunavut	GOOD: contaminant standards; accredited labs for water quality testing. NEEDS IMPROVEMENT: treatment standards; testing. LACKING: operator certification; public reporting.	C	C
Ontario	GOOD: treatment standards; contaminant standards; testing; accredited labs for quality testing; operator certification; public reporting.	B	A-
PEI	GOOD: testing; accredited labs for water quality testing; operator certification. NEEDS IMPROVEMENT: public reporting (but plans in works). LACKING: treatment standards; contaminant standards.	F	C-
Quebec	GOOD: treatment standards; contaminant standards; testing; accredited labs for water quality testing; operator certification. NEEDS IMPROVEMENT: public reporting (reports at the regional level only).	B	B+
Saskatchewan	GOOD: accredited labs for water quality testing; operator certification; public reporting. NEEDS IMPROVEMENT: treatment standards; contaminant standards; testing.	C	B-
Yukon†	GOOD: contaminant standards; testing; accredited labs for water quality testing; operator certification. NEEDS IMPROVEMENT: treatment standards. LACKING: public reporting.	D-	C-††
Federal Government	NEEDS IMPROVEMENT: evaluation and regulation of chemicals; formulation of standards for guidelines. LACKING: First Nations drinking water safety; binding minimum drinking water standards; recognition of a right to clean drinking water; tracking national drinking water data, trends and best practices.	Not Graded	F
Note: †Based on detailed proposed legislation. ††Will be higher if reforms are implemented.			

Table 3.5 National Sewage Report Card III (Sierra Legal Defence Fund, 2004).

CITY	SUMMARY	1999 GRADE	+/-	2004 GRADE
Brandon	Implemented 100% secondary treatment and UV disinfection. Combined overflow of up to 2.8 million litres per year.	D	+	B-
Calgary	UV disinfection added to 100% tertiary treatment. Additional upgrades in the works ($250 million).	A	+	A+
Charlottetown	Primary treatment only. Volume of discharges not monitored. Plans to upgrade to secondary by 2006.	E	+	E+
Dawson City	Still discharging one billion litres of raw sewage per year. Await funding for upgrade to secondary treatment.	F-	+	E
Edmonton	Upgrade to 100% tertiary treatment and UV disinfection.	B+	+	A-
Fredericton	Secondary treatment with UV disinfection. No major improvements since 1999.Low percentage of CSOs.	B	NC	B
Halifax	More than 65 billion litres of raw sewage discharged each year. Regional plants provide secondary or tertiary treatment.	E-/C	+	D
Hamilton	Upgrades to secondary and tertiary treatment. Discharges 5.9 billion litres of raw sewage each year. Only 88% of population served.	C-	+	C+
Montreal	Primary treatment only. No discernible progress made.	F+	-	F
Ottawa	Secondary treatment. Seasonal chlorine disinfection, no dechlorination. Overflow system controls installed.	C	+	B-
Quebec City	Secondary treatment with seasonal UV disinfection. Combined sewer overflow events reduced.	C	+	B
Regina	Enhanced secondary treatment with expanded UV disinfection. Extensive upgrades planned.	B	+	B+
Saint John	Reduction in combined sewers. Primary and secondary treatment. Almost 40% of population still do not receive treatment.	E	+	D
Saskatoon	100% secondary treatment. Minimal changes since 1999.	C+	NC	C+
St. John’s	More than 33 billion litres of raw sewage discharged. Primary sewage treatment plant under construction.	F-	+	E
Toronto	Toughest Sewer-Use Bylaw in country. Secondary treatment. Still discharge 9.9 billion litres of untreated sewage and runoff.	C/B	+	B-
Vancouver	Up to 22 billion litres of combined sewer overflows each year. Upgrades to 100% secondary treatment won’t be completed until 2030.	C-	-	D
Victoria	Preliminary screening, no treatment. More than 34 billion litres of raw sewage discharged each year.	F-	-	Suspen-ded
Whitehorse	Secondary treatment. Minimal progress since 1999. Efforts under way to reduce volumes of sewage. No raw sewage discharges.	B-	NC	B-
Winnipeg	100% secondary treatment. Reduced number of combined sewers, still one billion litres of combined sewer overflow per year.	C	+	B-
Whistler	100% tertiary treatment.	-		A
Yellowknife	100% secondary treatment with natural UV disinfection. Only minor changes since 1999.	B+	NC	B+

3.2.2. ***Transportation***

The results of the 1985 municipal infrastructure survey showed that roads, bridges, and sidewalks were in the poorest condition. The 1996 survey similarly confirmed that at the national level, roads, bridges and sidewalks were in greatest need for repair and that their condition, in comparison to other types of infrastructure, was getting worse. While transportation was not the category showing the greatest funding need in the 2007 survey, the per capita expenditure needed to upgrade existing infrastructure almost doubled since the 1996 survey, rising from \$384 per capita to \$686 per capita. In total, an investment of \$21.7 billion is needed for upgrading, as compared with the estimate of \$11.4 billion in 1996 (Table 3.6). Of the main findings, 65% of the upgrading needs were expressed by the larger municipalities, which was expected because most of the transportation systems in these larger communities were developed in the post-war period and many are in need of urgent repairs and replacement. While most of the new needs were also from the larger municipalities, a significant percentage (38%) was expressed from smaller, rural and northern communities, showing a need for expanded transportation systems in these regions.

Table 3.6 The municipal infrastructure sub-deficit for transportation infrastructure, in 1996 and 2007.

	1996	**2007**
Average cost to upgrade existing infrastructure assets	\$384/capita \$11.4 billion	\$686/capita \$21.7 billion
Average cost for new infrastructure needs	-	\$28.5 billion

The transportation network in Canada consists of more than 900,000 kilometres of roads and highways: the National Highway System (NHS) comprising approximately 38,000 kilometres of highway (Transport Canada, 2006) and 3,534 bridges (Transport Canada, August 16 2007). The municipalities, and the provinces and territories control approximately 73% and 25% of Canada’s road network, respectively. The federal government owns approximately 2% of the road network, which includes roads on Indian reserves, the Alaska Highway, roads passing through national parks, or found on other federal properties (Transport Canada, 1996). The little involvement of the federal government in road building and renewal has had its toll on the transportation network in Canada. In particular, roads and highway segments under federal jurisdiction have a higher average age, and the lack of federal intervention has led to insufficient investments, as federal taxation powers and revenues could help increase funding needed to bring road and highway networks to acceptable levels.

3.2.2.1. Dealing with Aging and Deteriorating Systems

Most of the existing roads and highways were built in the 1950's and 1960's to satisfy new needs imposed by the population growth, increases in the number of registered car users and suburban sprawl. Although traffic soared dramatically, as networks were built, much of the existing transportation infrastructure was not designed for the current traffic volumes and significantly heavier truck loads. Additionally, compared to many other countries, infrastructure deterioration in most Canadian communities is accelerated due to the aggressive winter climate and the use of de-icing salts. The illustrations (a) to (g) of Figure 3.2 demonstrate the progressive formation of a pothole in asphalt pavements.

Illustration (a) shows the cracking of the asphalt due to fatigue, or the repetitive traffic loading on a localised section of the pavement that has a base and sub-base that has not been compacted properly. Illustration (b) shows a crack propagating all the way through to the subgrade; the crack seen on the surface is reflective of the base and sub-base joint caused by differential settlement. During the winter months, water and snowmelt enter the existing cracks and pores in the asphalt and concrete pavements, due to poor drainage (illustration (c)). Freezing (illustration (d)) and thawing (illustration (e)) cycles cause expansion and contraction, damaging the internal structure of the pavement. Once frozen, the pavement has excellent load bearing capacity. Once thawed, the internal damage of the asphalt pavement's sub-layers has reduced the pavement's strength, which may no longer be adequate to support the traffic loads, thereby causing the asphalt surface to "cave-in" or break-up (illustration (f)). Upon continuous traffic loads and wear and tear, the remaining pulverized material is lost leading to the formation of a pothole, as seen in illustration (g).

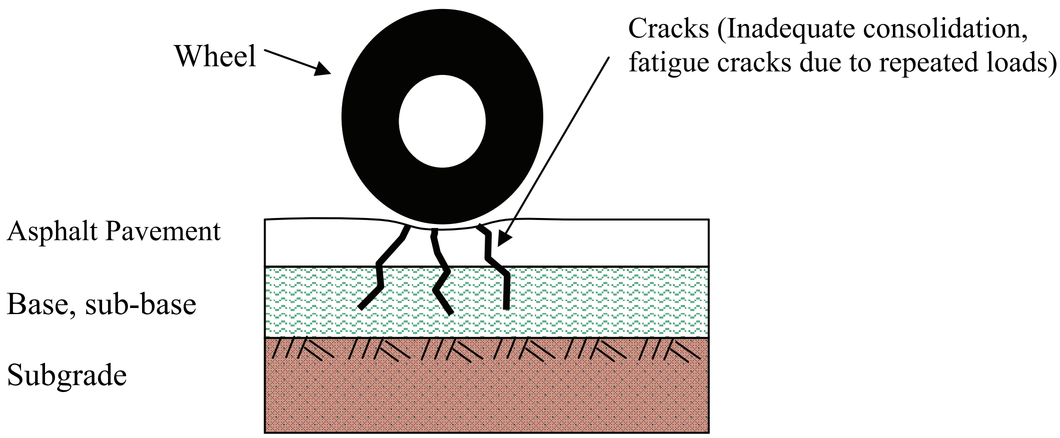

Figure 3.2 Steps in the formation of potholes in asphalt pavements (Mirza and Sipos, 2008). **(a)** Initial stages of pavement deterioration: formation of fatigue cracks.

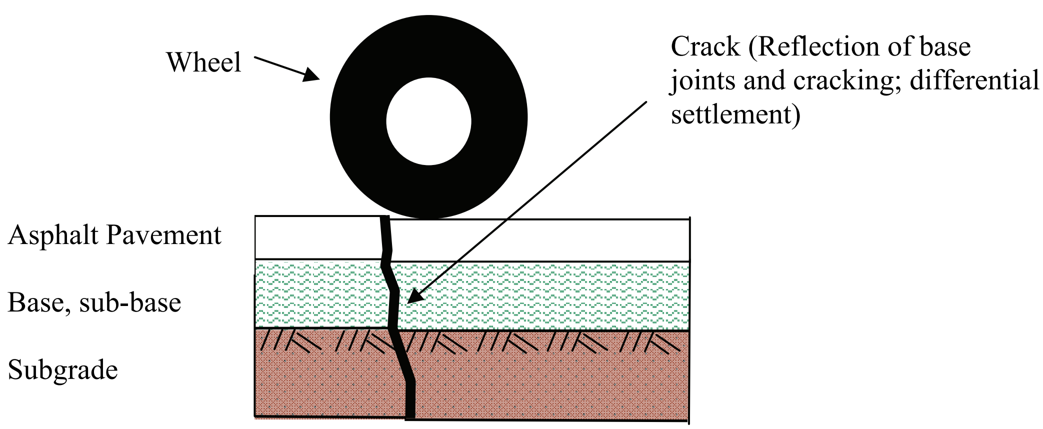

Figure 3.2 (b) Cracking due to differential settlement.

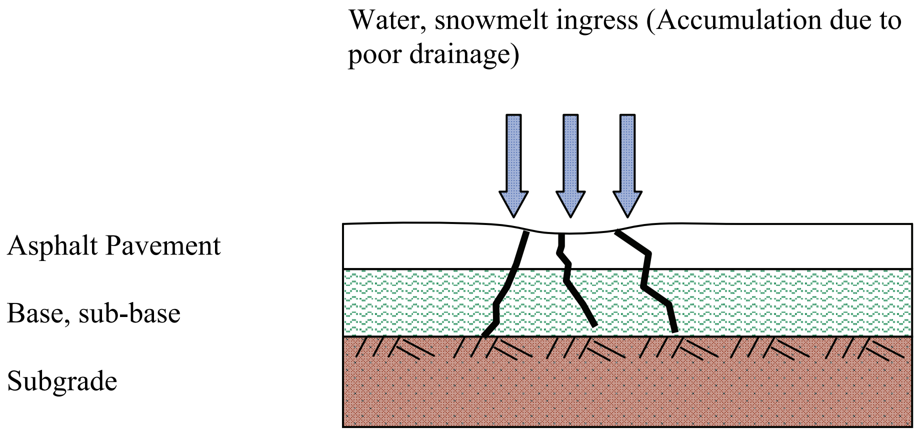

Figure 3.2 (c) Ingress of water and snowmelt

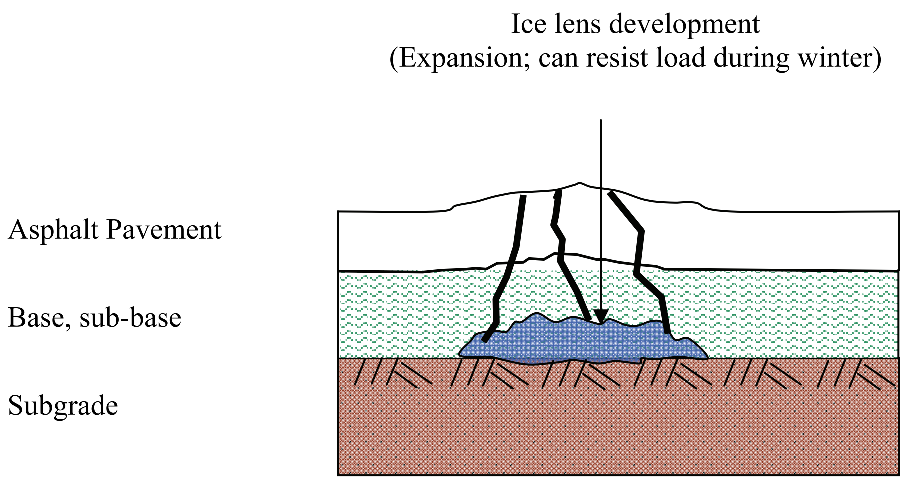

Figure 3.2 (d) Freezing

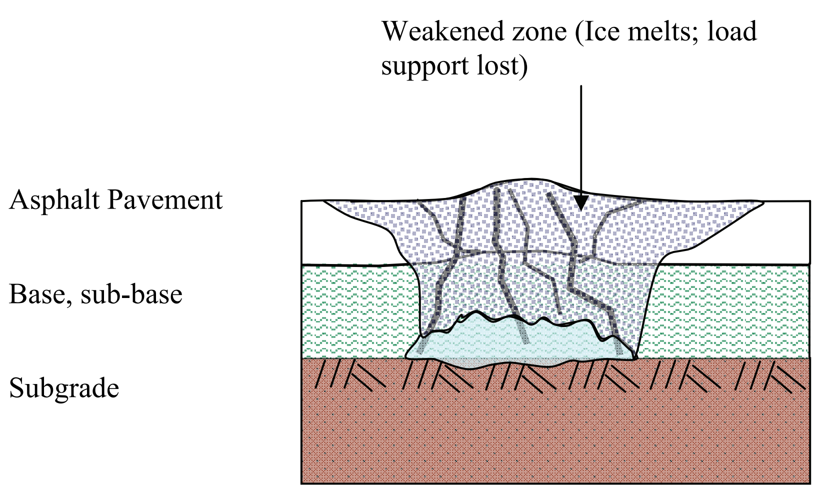

Figure 3.2 (e) Thawing

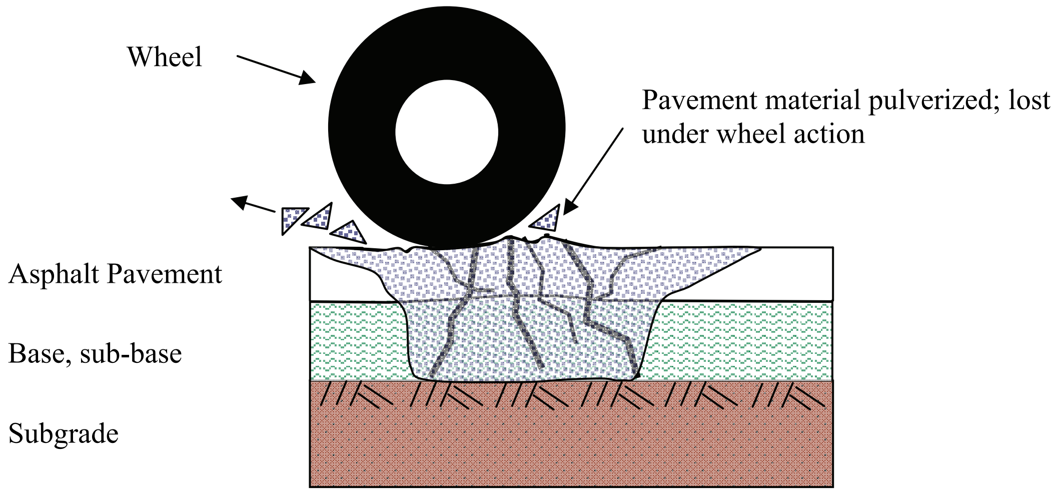

Figure 3.2 (f) Pavement break-up

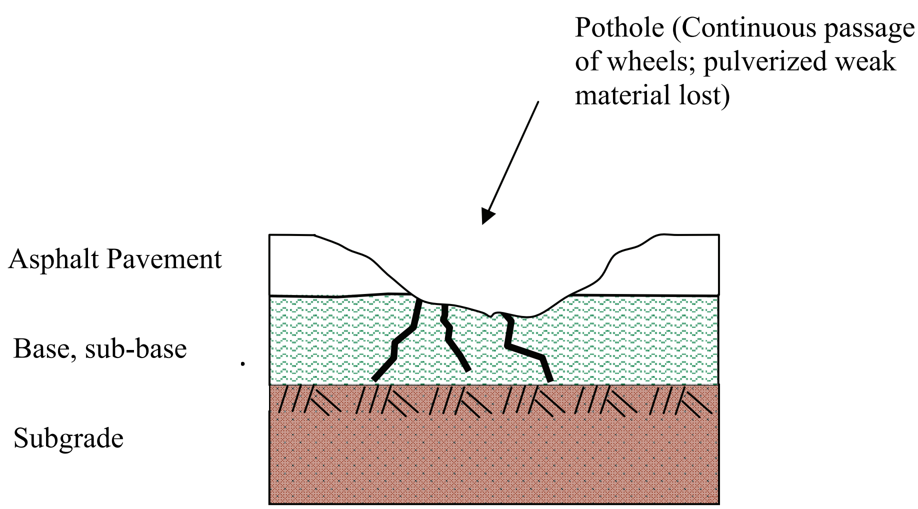

Figure 3.2 (g) Pothole formation

In the case of a concrete pavement, internal voids and cracking damage may leave room for more water to seep in and undergo freezing and thawing cycles, due to the increased permeability of the concrete. This latter situation is worsened with the ingress of de-icing salts, which causes a differential freezing temperature profile along the depth of the concrete. Considering a concrete block exposed to freezing temperatures and de-icing agents (Figure 3.3), the extreme top layer of the concrete will undergo a temperature drop due to exposure to the de-icing salts, which lower the freezing temperature (Figure 3.3 (a)). The difference in the temperature leads to internal stresses, as the top layer tends to expand (tension) and the subsequent layers which are freezing tend to contract (compression). Different areas along the depth of the concrete will also freeze at different times due to the effect of the de-icing salts and the large variation in the pore sizes on water distribution within the hydrated cement pores. This will also generate tensile stresses in the thin top layer, with compression in the layer immediately underneath it. This causes the upper layer to crack and disintegrate, causing scaling of the top surface (CEB, 1989).

Cracks allow further access for the ingress of water and de-icing salts into the concrete and they accelerate corrosion of the embedded reinforcing bars. The rust formed on the reinforcement as a by-product of corrosion, in turn, may increase the reinforcing bar's volume by as much as 600%. This increase in volume causes expansive forces within the concrete, leading to additional cracking and spalling.

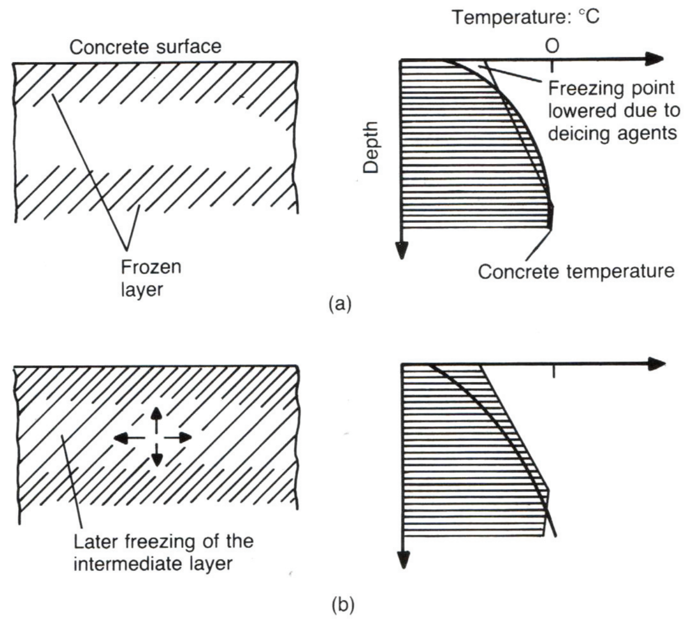

Figure 3.3 Differences in the timing of the freezing layers within the concrete (CEB, 1989).

Levels of deterioration have increased across Canada as routine maintenance has not been the common practice, and the deterioration caused by aggressive winters has accumulated over the years. Although potholes are usually repaired in the springtime, these repairs are typically temporary solutions to a recurring problem. A typical pothole repair is illustrated in Figure 3.4. This repair consists of simply patching the pothole, as is, with a cold- or hot-mix bituminous material. This material is then compacted. In light of saving time and money, the more lengthy process of preparing the pothole for a more adequate repair is avoided. As can be seen in Figure 3.4 (a), cracks extend beyond the area where the pothole is formed. Therefore, by patching the pothole, its weak, feathered ends and the cracked pavement around it are not dealt with. Over time, as vehicles pass over the patched repair, the feathered ends get removed and the cracks continue to propagate under load (Figure 3.4 (b)). As a result, the typical method of repairing potholes is not providing a fast, economical and sustained solution, but, on the hand, repairs are requiring their own repairs leading to higher costs, wasted time and short-term solutions.

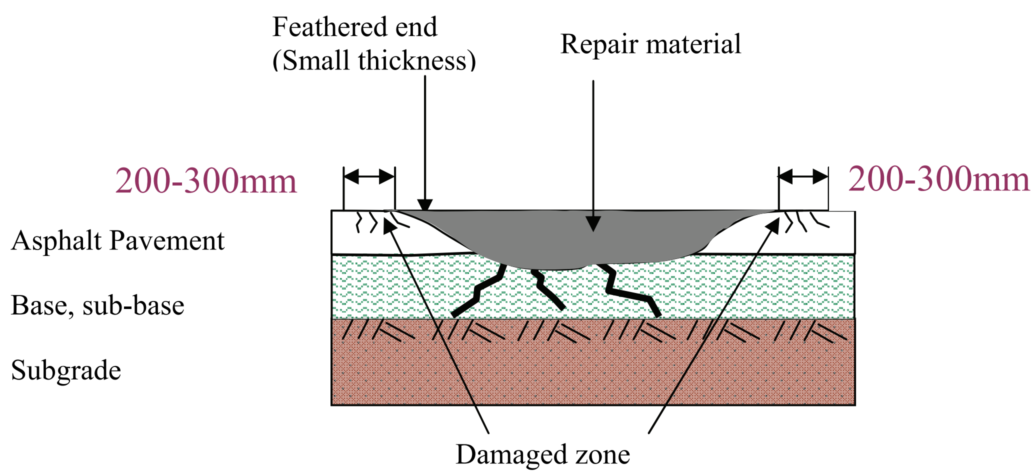

Figure 3.4 A typical pothole patch repair (Mirza and Sipos, 2008).
(a) Patch repair without pothole preparation.

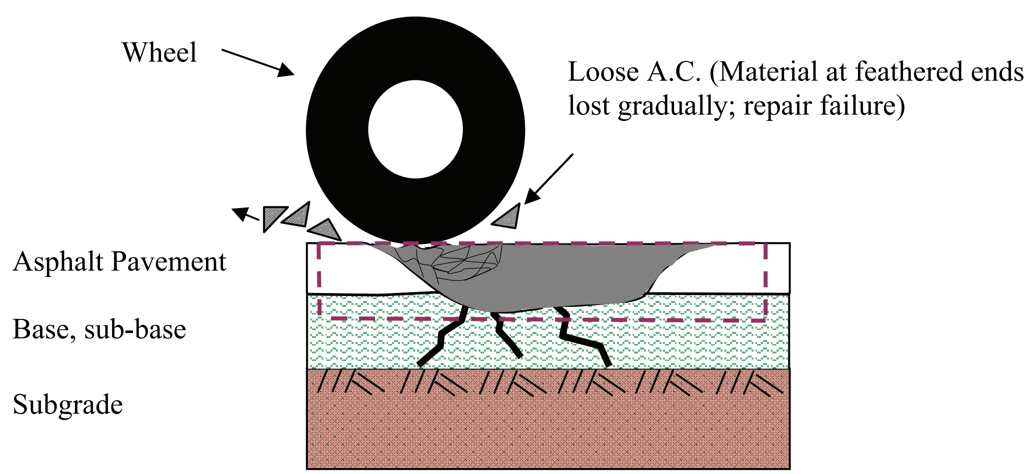

Figure 3.4 (b) Failure of the patch repair

Figure 3.5 illustrates the more effective pothole repair, which first requires preparation of the pothole. The area surrounding the pothole is milled to square edges to eliminate any weak feathered edges and surrounding cracks. This can extend 200-300 mm laterally around the pothole, or a greater surface can be milled if the surrounding area is severely deteriorated. Milling should also extend to the sub-grade to ensure adequate compaction (which caused the initial fatigue) and to prevent inadequate bonding between the new fill and the existing base materials. The milled area is cleaned by blowing out any debris or water, to prevent poor bonding with the fill. Cold-or hot-mixed asphalt material is then used to fill the square-edged milled area, though a hot-mix provides a superior bond with the existing material. The fill should be added in layers so that each layer is properly compacted. The milled area may also first be coated with asphalt emulsion to improve the bond between the old pavement and the new filler.

Inadequate investments have caused limitations to adequate levels of repair and maintenance, however, other constraints exist. For example, the rehabilitation of main arteries in metropolitan districts is usually most urgent due to more wear-and-tear and older infrastructure. However, projects are often deferred to avoid upsetting or inconveniencing the population or businesses that would be affected by street closures and construction, demonstrating how politics can act as a constraint.

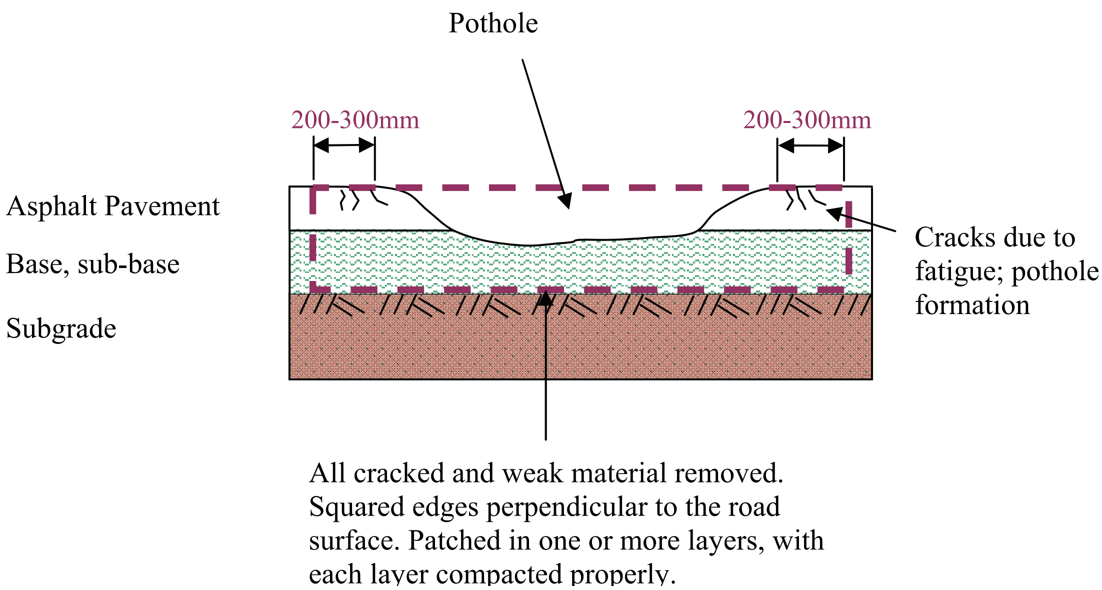

Figure 3.5 Effective pothole repair (Mirza and Sipos, 2008).

Transport Canada's 1988 study of the NHS revealed that 38% of the system was deficient "relative to minimum geometric design, serviceability (based on a 10-year projection of traffic), structural strength or riding comfort." Furthermore, 22% of the bridges within the NHS required major strengthening or rehabilitation within the following five years (Transport Canada, August 16 2007). A 1987 report by the Ontario Road Builders' Association (ORBA) stated that:

> "*3,796 bridges, or 32.5% of the bridges in [Ontario] will need to be rehabilitated or replaced during the next five years. Another 1,500 bridges do not meet normal highway loading standards. Sixty-one per cent, or 37,000 kilometres of municipal paved roads will need resurfacing within five years*" (CMHC, 1989).

It is clear to see that numbers would be higher today if much of this infrastructure was not appropriately maintained in the past decade. The improvement implemented in the transportation networks since the two 1980 studies needs a careful evaluation.

3.2.2.2. Where Does the Transportation Network Stand?

Canada has had its share of transport-infrastructure related tragedies since the beginning of this century, in addition to several bridge collapses. On December 11, 2006 a piece of concrete, approximately the size of a loaf of bread, fell from a railway overpass in Ottawa. The concrete fell onto a traveling vehicle below the overpass, damaging the car, but luckily not harming the driver (Sekeres et al, 2006). Large pieces of concrete falling from the overpasses have also been reported in Quebec. In the wake of the 2006 de la Concorde Bridge Collapse in Laval, Quebec, the Quebec Ministry of Transport issued, on July 19, 2007, a list of 135 bridges in Quebec that need thorough evaluations, consisting of inspections, coring and structural analyses. The concrete structures are deemed to have insufficient steel reinforcement to counter shear cracking, increasing the risk of failure if levels of degradation are high. Until the confirmation of the structural integrity of these structures through rigorous evaluation, heavy vehicles such as buses and trucks are not permitted to use these structures, as a preventative measure.

These measures have put considerable pressures on trucking companies, which rely on the closed bridges and overpasses for faster and, therefore, less costly operations. Moreover, events such as those described have raised the level of importance of infrastructure renewal in the public eye, many are concerned that their safety is at risk when crossing highways or bridges. Although Laval and other Montreal residents have experienced the latest Canadian "infrastructure tragedy", this and other similar recent international occurrences have raised a red flag among the general public across the country. A CBC news broadcast following the Minnesota Bridge collapse revealed that of Canada's 50,000 bridges, it is estimated that half are deficient either structurally, relative to serviceability, due to severe deterioration or due to a combination of these factors, suggesting that Montrealers are not alone and that the transportation infrastructure had not improved since the studies performed in the 1980's.

3.2.3. ***Transit***

Figure 3.6 shows the number of urban transit users between 1974 and 1998. The statistics are representative of 1,110 companies, including interurban transportation, school bus transportation, charter bus industry, shuttle services, sightseeing transportation and 100 urban transit companies, which provide service to approximately 97% of all urban transit users in Canada (Statistics Canada, 1998). The fluctuations can be attributed to the several factors turning citizens away from public transit, considering that many of these factors change over time, such as:

- Increasing transit fares to meet maintenance demands and new needs, and to follow suit with escalating fuel prices;
- Suburban sprawl, which leaves many inconvenienced by not having a transit service between city core and their homes;
- Frequent changes in transit service hours and unaccommodating transit schedules;
- Aging of the population, which leads many to drive cars in preference to public transportation because they feel it is a safer, more comfortable and time-saving mode of travel (Kohn, 2000); and
- Loss of public confidence in transit systems due to frequent service interruptions or slow service because of faulty infrastructure, or emergency repairs, and because of below capacity systems, which do not offer comfort to the rider.

The poor state of existing infrastructure will certainly discourage people from using public transit; the lack of new infrastructure to meet new service requirements would have a similar effect. Examples include new buses and metro cars to provide more frequent service, or larger parking lots and bicycle shelters at train or metro stations that can benefit those that are inconvenienced or not serviced by bus hours and bus routes.

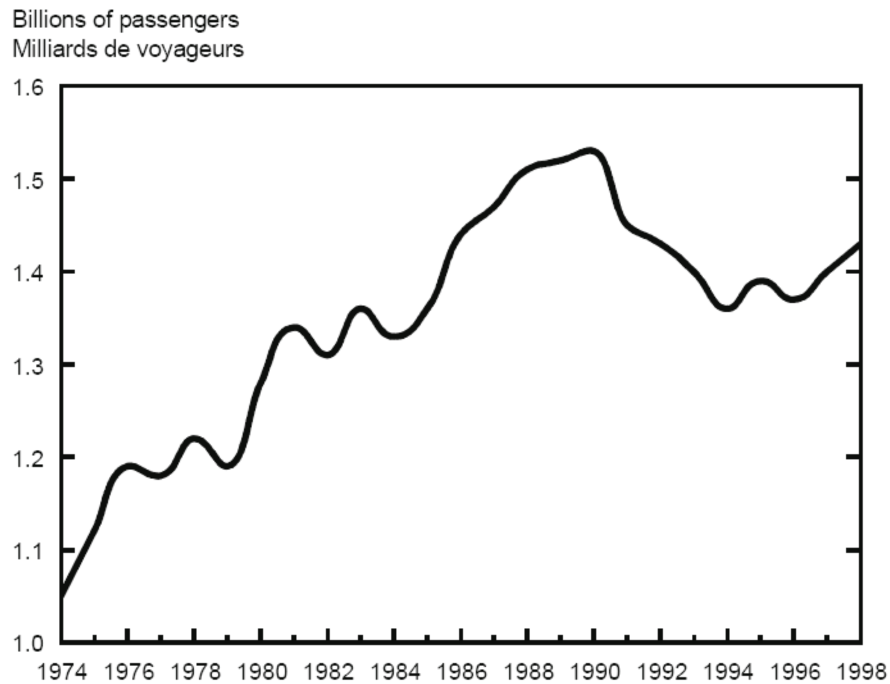

Figure 3.6 Number of urban transit passengers between 1974 and 1998 (Statistics Canada, 1998).

Figure 3.6 shows that the number of urban transit passengers has been steadily increasing from 1996 to 1998. In 2000, the ridership rose to 1.5 billion, which is close to the maximum of 1.53 billion passengers that used urban transit in 1990, which was available to 95% of the urban residents, representing roughly 61% of Canada's total population (MRC, 2002). Public ridership continues to rise as government investment in transit systems increases. The provincial government's share in transit capital investment has increased from 15% in 2000 to 40% in 2005. Similarly, the federal government investment has increased from zero to 18% during the same timeframe (CUTA, 2007). The municipalities, however, continue to cater for the largest of the expenditures in public transit infrastructure. Although investments are increasing, there still remains a shortfall in the investments needed to improve the existing transit infrastructure and meet the continually growing needs.

3.2.3.1. Transit in the Twenty-First Century

The results of a Canadian Urban Transit Association (CUTA) survey, evaluating local transit system needs in municipalities across Canada, between 2004 and 2008, revealed that there was an $8.3 billion shortfall within the $14.1 billion needed for new infrastructure to meet growing service demands (CUTA, 2005). Figure 3.7 demonstrates how this shortfall has been growing within the past decade, as adequate actions have not been taken to reduce the infrastructure deficit and to improve the state of the transit infrastructure. CUTA has revised the transit infrastructure deficit with a survey distributed to all of its transit system members and has found that $40 billion are needed over the next five year period from 2008 to 2012: 29% ($11.6 billion) for renewal and rehabilitation of existing transit infrastructure and 71% ($28.4 billion) for new transit needs. The survey responses show that the $40 billion deficit represents 95% of Canada's total transit operations (CUTA, 2008). Figure 3.8 demonstrates the areas where rehabilitation and replacement are most needed. Rolling stock needs the most upgrading, followed by fixed guideways (or rights of way), buses and maintenance facilities.

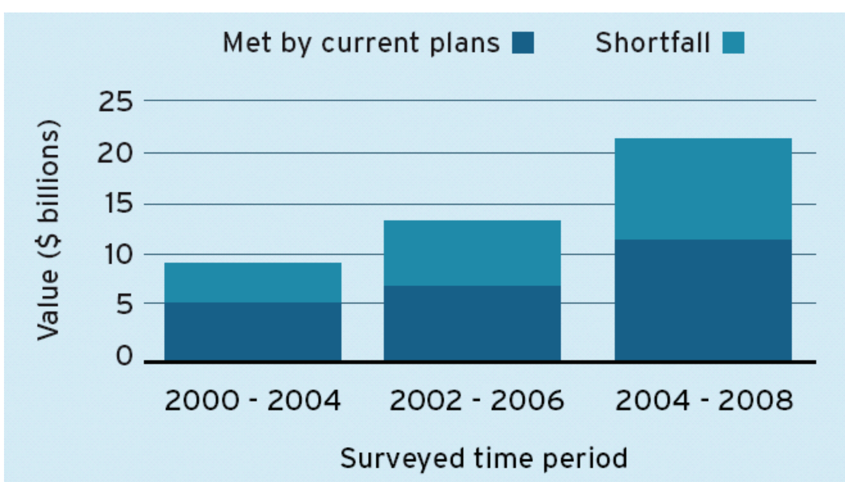

Figure 3.7 Transit infrastructure needs in Canada, for the 2000-2008 period (CUTA, 2005)

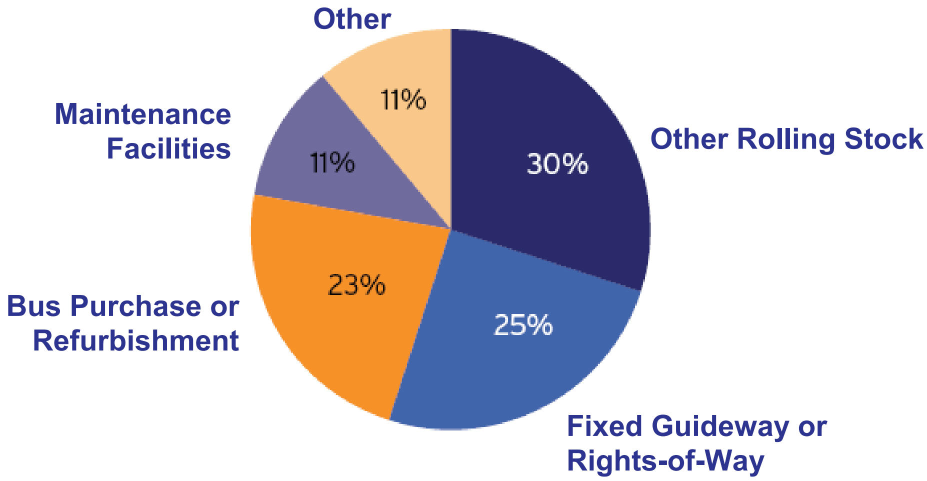

Figure 3.8 Transit system rehabilitation and replacement needs 2008-2012 (CUTA, 2008).

According to the *2007 FCM-McGill infrastructure Survey*, it will cost municipalities $22.8 billion for upgrading needs, which has risen tremendously since the 1996 survey when only $3.05 billion was needed. An additional $7.7 billion is needed for new infrastructure, which in addition to the $22.8 billion for upgrading needs, is consistent, but slightly less than the CUTA projection (Table 3.7). Most responses for the transit category were received from the larger municipalities. This would be expected, since the smaller rural and northern communities have limited transit services. However, it is surprising that these smaller communities did not show a greater immediate and future need for transit systems. Instead, new transit systems require considerable investment in the larger municipalities to meet the higher service demands. The latter is also consistent with the responses to the CUTA survey which show that 73% of new infrastructure needs are for larger cities (Toronto, Montreal and Vancouver), 25% for other census metropolitan areas and only 2% of new needs are for smaller cities and towns (CUTA, 2008).

Table 3.7 The municipal infrastructure sub-deficit for transit system infrastructure, in 1996 and 2007.

	1996	2007
Average cost to upgrade existing infrastructure assets	$3.05 billion	$22.8 billion
Average cost for new infrastructure needs	-	$7.7 billion

*3.2.4. **Cultural, Social and Recreational Facilities***

According to the Canadian Parks and Recreation Association, about $15 billion were needed in 2007, to upgrade sports and recreational facilities. The 1996 and 2007 municipal infrastructure surveys included other public facilities (Table 3.1). In 1996, the cost to upgrade existing infrastructure was $7.55 billion and in 2007, this number increased to an amazing $40.2 billion. The survey results showed that $18.1 billion are needed to meet new infrastructure needs (Table 3.8). The responses for this infrastructure category were quite distinct for larger and smaller (i.e., rural and northern) communities. The high average cost to upgrade existing infrastructure comes from the largest municipalities (i.e., Montreal and Toronto), while it is primarily the smaller municipalities, with populations less than 100,000, which showed the greatest need for new social and recreational infrastructure.

Urban population growth and rapid aging of public facilities may best explain the upgrading needs being more prevalent for the larger municipalities. A lack of funding over the past 30 years has been one of the main causes for the present backlog of deterioration. Therefore, whatever funding was directed to the municipalities over the past years were directed primarily to infrastructure thought to have the most prevalent needs, such as transportation, transit and water/wastewater systems (Mirza, 2007). For this reason, cultural, social and recreational facilities have been neglected and require immediate attention.

Table 3.8 The municipal infrastructure sub-deficit for cultural, social and recreational facilities, in 1996 and 2007.

	1996	2007
Average cost to upgrade existing infrastructure assets	$7.55 billion	$40.2 billion
Average cost for new infrastructure needs	-	$18.1 billion

3.2.5. *Waste Management*

The final infrastructure category – waste management – remains the category with the least needs, according to the 2007 FCM-McGill survey responses, yet the needs have escalated since the 1996 survey. In 1996, approximately $1 billion was needed to upgrade existing waste management infrastructure. In 2007, this need has risen to $7.7 billion. The new needs are about $4.3 billion. There is great potential for upgrading the infrastructure in this category to more sustainable and environmentally-friendly alternatives. If another survey were conducted in five years, waste management will most likely be an area with a large increase in new needs, as environmental concerns continue to receive more attention, and become important elements of political, social and corporate agendas. To date, very little research has been performed to identify the exact needs in this area. These can, therefore, not be compared to the present survey findings, which are summarized in Table 3.9.

Table 3.9 The municipal infrastructure sub-deficit for waste management, in 1996 and 2007.

	1996	2007
Average cost to upgrade existing infrastructure assets	$1 billion	$7.7 billion
Average cost for new infrastructure needs	-	$4.3 billion

3.3 Waterfront Infrastructure

While waterfront infrastructure was not included in any of the surveys, it constitutes one of the most important infrastructure categories in terms of tourism and international trade, and thus, international competitiveness. The knowledge of the condition of the waterfront infrastructure in Canadian ports and harbours is inadequate, as it has not been the subject of any known recent condition assessment surveys. As port activities are overseen by the Port Authorities, which operate under federal jurisdiction, this class of infrastructure was not included in the FCM-McGill surveys. Economic reports are clear in stating that waterfront infrastructure is no exception to the deteriorated infrastructure seen across the country and requires immediate attention, if Canada is to move forward as a competitive country. Yet, a thorough assessment of the present state of health of the waterfront infrastructure is needed. The Association of Canadian Port Authorities (ACPA) has applied to Infrastructure Canada for a grant to undertake a complete study of the current state of Canadian waterfront infrastructure (ACPA, 2006). In the meantime, the ACPA is working with other groups to improve the state of marine-infrastructure.

Aggressive marine environments, the impact of ships and the damage caused by heavy equipment and vehicular traffic (e.g., cargo carrying vehicles) are the predominant causes of deterioration of waterfront infrastructure. The large difference in the waterfront environments and the facilities in each port make it difficult to conduct a general assessment of the condition of these facilities in a broad study of the infrastructure across Canada, without the help of the Port Authorities. It is therefore recommended that a survey similar to that conducted by McGill and the FCM focus solely on this infrastructure category. It is also hoped that the Port Authorities will cooperate in completing this type of survey, as waterfront infrastructure acts as a vital part of the overall transportation network in Canada.

3.4 Factors Influencing the Infrastructure Deficit

The results of the *2007 FCM-McGill Infrastructure Survey* note the infrastructure categories with the greatest needs and shortfalls. However, unlike the past surveys, the 2007 study was not only aimed at identifying the deficits for each infrastructure category, but it was also aimed at identifying the factors that caused rapid escalation of these deficits. Municipalities were asked if they "strongly disagree", "disagree", "somewhat disagree", are "unsure", "somewhat agree", "agree" or "strongly agree" that the following factors are contributing to new and/or expanding infrastructure needs and creating additional funding requirements:

- Aging of infrastructure
- Climate Change
- Population Growth
- Urbanization
- Suburban Growth
- Red Tape
- Lack of Training Opportunities
- Environmental Regulations
- Financial Regulations
- Managerial Regulations
- Safety Standards
- New Environmental Regulations
- New Wastewater Requirements
- Lack of Qualified Personnel
- Lack of Technical and Managerial Expertise

The number of municipalities which provided a classification for each of these factors varied. However, more than 48 municipalities responded in each case. Figure B.1 in *Appendix B* consists of pie-charts showing the classification provided for each factor as a percentage of the responding municipalities. The main results are as follows (percentages represent the weight of a particular classification for each factor and do not provide the weight of responses received for each factor):

- Aging of infrastructure (68%), followed by population growth (28%) and new environmental regulations (29%) are the factors that the largest percentage of respondents "strongly agreed" are compounding the infrastructure deficit;

- Most municipalities "agreed" that environmental regulations (42%), new environmental regulations (41%), population growth (40%) and urbanization (32%) are the factors compounding the infrastructure deficit;
- Lack of training opportunities (23%), lack of technical and managerial expertise (17%) and climate change (14%) are the factors for which municipalities most "disagreed" to having an impact on compounding the deficit;
- Most municipalities were unsure about the influences of managerial regulations (32%) and climate change (30%) on the deficit's escalation.

3.5 Canada's Position Among Other Nations

The current situation may seem grave in Canada, but the infrastructure deficit and the state of facilities are comparable with those in the U.S.A. The latest infrastructure report card developed by the American Society of Civil Engineers (ASCE) gave a failing grade 'D' to the American infrastructure and noted that $1.6 trillion dollars was needed within the next five years (2008-2012) to bring their infrastructure to acceptable levels. The most recent infrastructure deficits of various other countries and regions around the world are listed in Table 3.10.

Table 3.10 International infrastructure deficits.

Year	Deficit ($Billion)	Country/Region (Sources)
2000	7.7	Northern Ireland (Confederation of British Industry) (BBC, 2001)
2007	90	Australia (Business Council of Australia) $6.4B in lost production per year (Dunlop, 2008)
2006	145	Indonesia (Asian Development Bank) (Greenwood, 2006)
2007	500	India (Planning Commission, Government of India) (Joshi, 2007)
2007	600	United Nations Economic and Social Commission for Asia and the Pacific Region (UNESCAP) (Srinivasan, 2007)
2006	1,000	East Asia (Japan Bank for International Cooperation, the World Bank, the Asian Development Bank) (Greenwood, 2006)
2005	1,600	U.S.A. (ASCE, 2008)

The Canadian infrastructure deficit of $123.6 billion to upgrade existing infrastructure, seems low in comparison to those of other countries, but is nevertheless a problem that needs immediate attention. The International Institute for Management Development (IMD) in Switzerland published a world competitiveness report in 2003, ranking countries according to their infrastructure debts. Canada ranked sixth out of 10 countries with the U.S. having the highest debt (Vander Ploeg, 2003) (Figure 3.9).

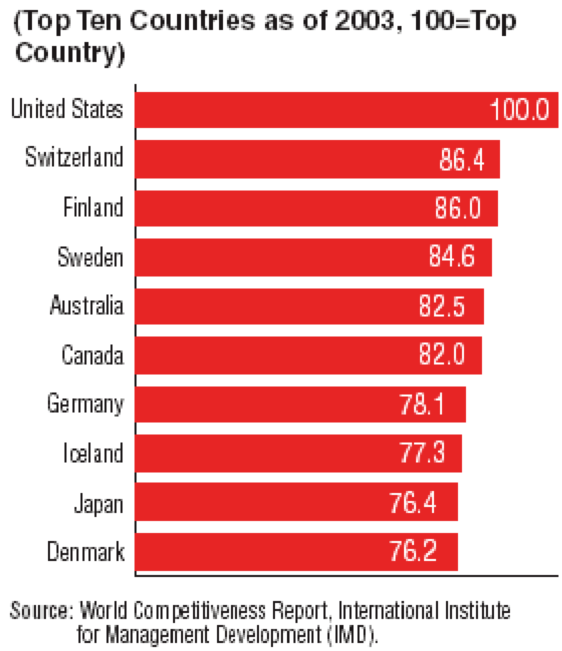

Figure 3.9 World competitiveness report: infrastructure debt rankings by country (Vander Ploeg, 2003).

CHAPTER 4

CURRENT TRENDS

4.1 Introduction

Some awareness of the infrastructure crisis does exist presently, however, many politicians and citizens lack the information needed to clearly assess the severity of the infrastructure crisis. It is very difficult to understand the pain and suffering of those who lost a loved one due to an infrastructure-related tragedy, such as a bridge collapse or transit accident, or the aggravation of someone who, years after a water supply contamination, still needs medical treatment. Yet, the frequency of these events is causing fear among many others who were not directly affected by these tragedies, but who are thinking "this can happen to me or to my family at any time". These people generally fear aspects of the infrastructure that are visible to them everyday, such as exposed and severely corroded rebar under an overpass, or the common culprit for damaged cars and public outrage: the pothole. Many people fail to focus on other issues that are equally important, because they are "out of sight and out of mind", or because they affect them only indirectly. While the "general public" (i.e., in this context, people whose field of study or whose occupation is not related to infrastructure in any way) should be educated on the causes and the consequences of the deterioration in the various infrastructure.

4.2 Public Point of View

The responses to the 2006 *IPSOS/REID Municipal World Survey* (Section 3.1.2) reflect the way the general public rates the quality of the different infrastructure types. The responses are representative of the views of 1,173 respondents from the different provinces. The main *Municipal World Survey* responses are shown in Figure 4.1, and they demonstrate the public view of the infrastructure assets in their communities to be in better condition than the rankings provided by the municipalities. In particular, the public claimed that 32% of sewage treatment facilities were in a “declining or desperate condition”. Comparatively, the 1996 FCM-McGill survey responses ranked 58% of sewage treatment facilities as being in “need of repair/in unacceptable condition”. Although not ranked as poorly as by the municipalities, public opinion was consistent in suggesting that roads and highways were in greatest need for repair, substantiating the idea that what is “out of site and out of mind”, as is underground infrastructure, water treatment facilities and power generation is often ignored. Public transit is another major area of concern to the public, as are schools, which are not included in any of the recent infrastructure surveys because they do not fall in the municipal jurisdiction.

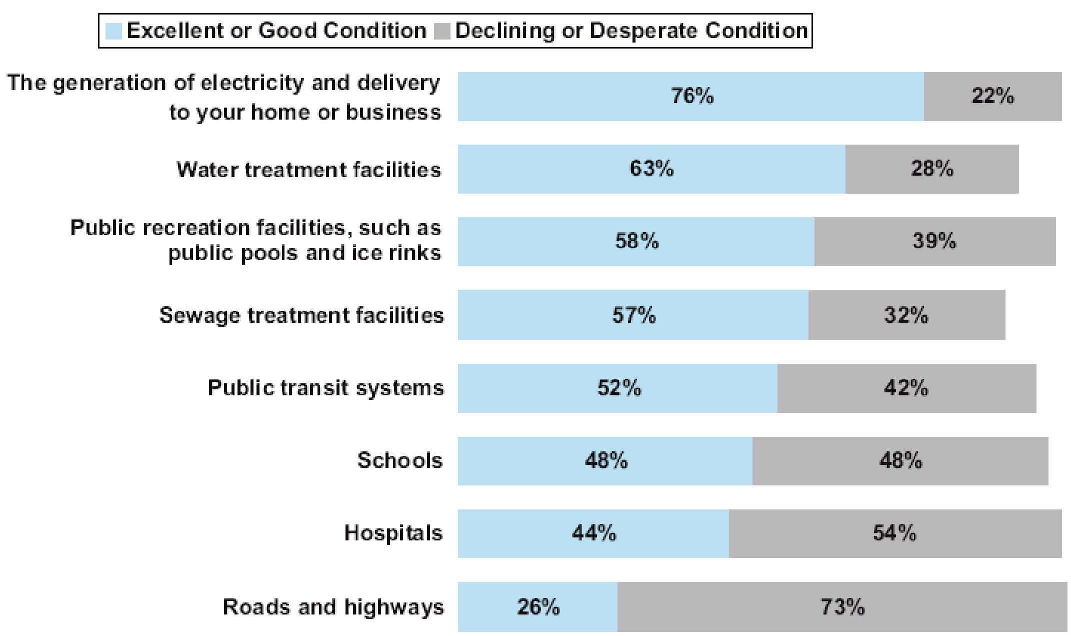

Figure 4.1 Public opinions on the state of infrastructure assets from the *IPSOS/REID Municipal World Survey* (Gunther et al, 2007).

As with many other issues, public opinion frequently changes with the turn of events and with increased media coverage of these events. Montreal’s winter snowfall records of 2007-2008 (a little more than 347cm), for example, were close to reaching the 1971 record (383cm). The winter's extreme weather conditions and the way the City of Montreal dealt with these abnormal volumes of snow left many outraged and clearly proved to the city management that snow removal equipment, and the capacity of storage facilities and dumps were inadequate. Many had to depend on the City's metro and other forms of transit, due to the long wait for snow clearing in many boroughs. In many cases, the frequency of bus and train pick-ups was inadequate for the needed increase in service and capacity. Furthermore, after such a harsh winter, it was inevitable that the yearly trend of emerging potholes would be more excessive than usual. Therefore, one harsh winter has brought out flaws in the state of infrastructure assets and the management of the services provided by these assets. One would therefore expect that after a long and dreadful winter, the general public opinions of infrastructure in their community would change. Similarly, recent media attention on major pipe breaks in Rivière des Prairies, on the east end of the Island, and on the possible installation of toll booths on Montreal bridges would have a similar effect.

Thus, post-publication of the revised infrastructure deficit and a time when infrastructure has become a popular news item for many of the reasons listed above, is also a time for a revised evaluation of the public opinion. For the purpose of this paper, a more general survey was sent solely to people in and around Montreal (e.g., Laval, the South Shore, etc.), for convenience and to question people who have either directly or indirectly been affected by events such as the Pie-IX pipe burst, in Montreal in 2002 and the 2006 de la Concorde Overpass collapse, in Laval. Even if the respondents' daily lives were not affected by these events, the results show that the events have "hit close to home", leaving many fearful and with greater awareness of the infrastructure crisis. Furthermore, the lack of capacity of snow dumps, huge potholes and slow transit services have particularly affected many citizens during the past year. *Appendix C* presents this 2008 *Municipal Infrastructure Public Questionnaire* and assembles all of the responses received for each of the 13 questions posed; the main survey results follow.

4.2.1. *The 2008 Municipal Infrastructure Public Questionnaire*

4.2.1.1. General Information

The first part of the survey was aimed at gathering general information about the 64 respondents. As the respondents also included civil engineers, civil engineering technicians and students studying in the area of infrastructure design and management, asking the respondents to include their occupation made comparison of the results between these people and "the general public" much simpler. Similarly, knowledge of the age groups of the respondents was also useful for comparison purposes. The results to some questions were specific to certain age groups. Lastly, respondents were asked to specify their municipality and boroughs of residence. As it is not unusual for a Montrealer to travel from different points on and off the Island, it is difficult to associate responses to certain areas. Instead, it was assumed and often specified by the respondent that responses were not limited to their communities per se, but to the state of the infrastructure around the City (their home, work place, school area, etc.) in general. However, some questions had specific responses from respondents from certain boroughs. For example, respondents living in areas right off the Island of Montreal were more familiar and accepted practices, such as water-metering, because this is common practice in their district. A review of these relationships follows.

The respondents included a cook, administrative assistants, educators, engineers, nurses, social workers, etc. As mentioned, a complete list of the responses to this and all other questions can be found in *Appendix C*. The highest number of responses was received from respondents in the 20-25 year age group (39% of respondents). There was a fairly consistent response rate amongst the other age groups between 26 and 60 years of age (11-16% response rate for each group). No responses, or very few were received from those under 20 years of age or greater than 60, respectively. As this survey was meant to gain a general idea of how people in Quebec perceive the state of their infrastructure, the latter is due to limited distribution of the electronic survey to people within these age groups.

The survey was simply passed on by various people to colleagues and classmates, thereby often excluding retirees, or students in colleges and schools. However, respondents were widely spread out across the Island of Montreal – from the West Island to the East end – and around the Island. The boroughs represented are shown in Figures C.1 to C.3, in *Appendix C*.

4.2.1.2. Public Perceptions of the Crisis

The respondents were first required to state how they perceive the state of infrastructure in Quebec, by selecting a statement that best described the magnitude of the crisis from a list. The majority of the respondents (81%) selected the statement claiming that Quebecers are facing "an infrastructure crisis - more changes than just increased spending are needed to improve the state of our infrastructure". Only 9% of respondents claimed that what Quebecers are facing is a "small problem that can be overcome with increased government spending". Luckily, only one respondent felt that the issues related to infrastructure are drawing too much media attention and that the infrastructure in their community was in an acceptable state. On the other hand, 9% of respondents selected the statement reading "we're facing problems with our infrastructure?"

Approximately 80% of the respondents "definitely" agreed that the de la Concorde Overpass and Minnesota Bridge collapses, as well as the Pie-IX pipe burst and other tragic events have made them more concerned and aware of the importance of infrastructure systems for the functioning and safety of a community. Another 7% and 3% of respondents "somewhat" agreed or did "not at all" agree with the same statement, respectively.

4.2.1.3. The State of Specific Infrastructure Types

The respondents were asked to rank the following main infrastructure categories according to the categories they felt are in the most deteriorated state and are in the greatest need for repair. These were ranked from 1 to 6, where '1' is the infrastructure category with the greatest need for repair and '6' is the infrastructure category with the least need for repair. The responses varied, but the following ranking scheme is representative of the majority of responses received for each infrastructure category:

Infrastructure Category	Ranking
Transportation	1
Watersupply	2
Wastewater and stormwater	3
Waste management	4
Transit	5
Social, cultural, community and recreational	6

As with the 2006 *IPSOS/REID Municipal World Survey*, according to the public, transportation infrastructure is in the greatest need of repair (55% of respondents). Infrastructure categories that require the least need for repair are transit (34%), contrary to what was expected after the last survey, and social, cultural, community and recreational facilities (67%).

The respondents were also asked to rank the main infrastructure categories according to the ones they felt are negatively affecting Canada's international competitiveness, economic growth and the quality of life of Canadians due to their present deteriorated state. Again, these were ranked from 1 to 6, where '1' is the infrastructure category with the greatest negative impact and '6' is the infrastructure category with the least impact. The categories were ranked as follows based on the majority of responses:

Infrastructure Category	Ranking
Transportation	1
Transit	2
Watersupply	3
Wastewater and stormwater	4
Waste management	5
Social, cultural, community and recreational	6

Transportation infrastructure was again ranked first, thereby signifying that it is perceived as having the greatest negative impact on Canada's international competitiveness, economic growth and the quality of life of Canadians. As would be expected, transit was ranked second, followed by watersupply and wastewater and stormwater systems, which most people ranked third or fourth. The respondents expressed the opinion that waste management and public facilities (social, cultural, community and recreational facilities) had the least impact on the above factors.

4.2.1.4. User pay models

The respondents were questioned about their acceptance of two different user pay models for transportation and water supply infrastructure, namely, toll booths and watermeters. In the first case, they were asked whether or not they would be willing to pay a toll when driving over a major Canadian bridge and highway, if the money would be used to implement routine maintenance programs of bridges and highways. Similarly, in the second case, the respondents were asked whether they would accept the installation of watermeters in their community, if it meant that the money would be used to implement routine maintenance of the water distribution systems, sewage disposal systems and water treatment facilities in their community. Each of these questions was followed up with a question asking the respondents if they would have had the same opinion if they were asked these questions 10 years earlier. They were also given the chance to give reasons why they were against the user pay models, when applicable.

Overall, the respondents had mixed feelings about implementing toll booths: 45% would "definitely" be willing to pay a toll for the above-mentioned reasons, 34% said "maybe" and 20% said that there is "no chance" they would be willing to pay a toll. A little more than half (52%) of those who responded "definitely" would have supported the same decision 10 years ago. Therefore, close to half (48%) would not have agreed to the installation of tolls if they were asked the same question 10 years ago, however, they have changed their minds, most likely due to the deteriorated state of highways and overpasses, and due to recent events. Of those who would “maybe” agree to the installation of tolls, 45% would not have had the same opinion 10 years ago. Approximately half of those who responded “no chance” would have had the same opinion. From the comments received, disapproval of toll booths in Canada is primarily due to the argument that the Government manages the funds poorly and that there is no guarantee that the money that drivers will spend on tolls will be used for the sectors promised. Many claimed that they are already paying enough for the license fees and the gas tax and that this money should be sufficient if appropriately allocated to improving the conditions of transportation networks.

As with the tolls, the respondents were torn between accepting or not accepting the installation of watermeters in their communities: 44% would “definitely” be willing to accept watermeters in their communities, 41% said “maybe” and 15% said that there is “no chance” that they would be willing to accept watermeters. Of the 28 respondents who would “definitely” accept the installation of watermeters, 18 said that they would have had the same opinion 10 years ago (64%), seven respondents (25%) said that they would not have; others were unsure or the question was not applicable to them (i.e., respondents would have been too young). Of those who responded “no chance”, no one said that they would have had a different opinion if asked the same question 10 years ago. Here, most people who rejected the idea of watermeters had similar reasons as the objections given for tolls. People felt that the money from existing taxes should be spent more appropriately. Therefore, while many seemed skeptical that money would be used for maintenance of underground infrastructure, many did express interest in monitoring consumption and paying some fees if it meant that people would be more conscientious about their water usage. One respondent suggested educating the public on the matter of water conservation before implementing additional fees.

It is interesting to note that 60% of the respondents in age groups greater than 51 years of age responded that there was “no chance” that they would be willing to pay a toll. Students who responded may be more concerned with the public transit for the time being, while they are maybe also less skeptical as to how their tax dollar was being spent. Half of the respondents who said “no chance” to water-metering were from these same age groups. The lower age groups seemed to have stronger opinions about water-metering, probably because it is a topic that is applicable to them at this stage.

4.2.1.5. Primary Concerns

The respondents were asked to rank a list of impediments to successful rehabilitation and maintenance of infrastructure from 1 to 6, where ‘1’ signifies the greatest impediment and ‘6’ signifies the least impediment. The majority of responses for each impediment lead to the following ranking:

Impediments	Ranking
Red Tape	1
Political inaction	2
Lack of knowledge of the problems associated with inadequate upkeep and management of infrastructure by politicians	3
Funding shortage	4
Lack of knowledge of the problems associated with inadequate upkeep and management of infrastructure by the community	5
Lack of qualified personnel	6

Red tape and political inaction are the factors that most respondents felt were impeding successful rehabilitation and maintenance, followed by lack of knowledge about the problems associated with inadequate upkeep and management of infrastructure by politicians. Funding shortages and lack of knowledge about durability, upkeep and management of infrastructure by the community were of minimal concern. The respondents felt that lack of qualified personnel was the least impediment.

Two open-ended survey questions were meant to gather the primary concerns of the public. The first asked whether there were specific types of infrastructure that concerned them and if yes, what concerned them the most about these assets. The second question was optional, asking respondents to list their primary concerns about the state of infrastructure. The specific infrastructure assets that were most listed as being a concern to the public were roads (particularly potholes), bridges, and water distribution systems, in that order. Other concerns were related to the transit systems, snow removal, water treatment, and waste management. In terms of more general concerns, most people expressed fear of other more tragic events occurring and uneasiness to the thought that actions were not being taken promptly to improve the current situation, be it through policies, best practices, or education. Therefore, while the general public seemed to list concerns related to fear of jeopardized health and safety, and expressed resentment towards the inappropriate allocation of existing funds, the respondents who have an educational or work background that is related to the area of public works listed concerns related to the planning and management of infrastructure. For example, these respondents stated their objections to:

- Focus being placed on new construction and not enough on rehabilitating and maintaining the existing assets;
- Rough and "patchy" techniques used for quick road and pothole repairs;
- Lack of an enforced maintenance plan for all infrastructure projects;
- Lack of creative financing alternatives;
- Present lowest-bid tendering process that does not consider the contractor's plans for future maintenance and life-cycle performance of the infrastructure facility;
- Lack of technical knowledge of individuals making administrative decisions;
- Inertia and delay in adopting new materials, techniques or practices, used successfully in other countries;

- Lack of an immediate response to change with an immense deficit to overcome; and
- Lack of funds being diverted to improving infrastructure asset management.

A partial list of responses to the open-ended questions is presented in *Appendix C* under questions (8) and (12). A complete list is available upon request.

4.2.1.6. The Infrastructure Deficit

When asked where Canada's municipal infrastructure deficit stands today, many respondents chose the correct category of $100 to $125 billion, but overall, most responses (52%) were within the broader range of $75 to $150 billion. Six people actually estimate the present deficit to be greater than $200 billion.

4.3 Government

Many of those who responded to the public municipal infrastructure survey expressed their concern for the lack of technical knowledge of decision-makers in infrastructure planning and project prioritization. Whether in administrative positions or politics, many of these decision-makers are unaware of the different deterioration modes, their consequences and the preventative measures, or maintenance needed for the upkeep of assets, yet they make major decisions related to these topics. While the following section is not aimed at highlighting the issues which are not and that should be addressed by all three orders of government, it is meant to make the reader aware of the more general concern that the infrastructure crisis has merely been acknowledged by the political leaders. There are still provincial elections without any mention of infrastructure among the list of political priorities. The government infrastructure programs that are created, typically last as long as the elected party's tenure. This leaves the next elected official with the responsibility of developing a program to address a backlog of infrastructure needs that could not be addressed with the previous program, due to its limited funds and limited duration. The latter fails to address the sustained long-term planning needs.

In the last provincial election in Quebec, which was held after the de la Concorde Overpass collapse, the only mention of infrastructure in the Leaders' televised debate, was when the Action Démocratique Leader tried to blame the Liberals for having hidden, from the public, documentation pertaining to potential problems related to the overpass. Besides using the word "infrastructure" to try to bring down the other party, no mention was made about improving the state of health of infrastructure, or to acknowledge the overpass collapse as a problem and to acknowledge that actions should be taken to prevent any recurrences.

It would not be fair to suggest that the three orders of government have not begun to take remedial actions, but rather much too slowly. The steps being taken are totally inadequate to address the problems that need immediate attention. Examples of recent actions include:

- The Big City Mayors' Caucus of the FCM had proposed that a National Transit Strategy be implemented to ensure dedicated investment ($2 billion per year by the federal government in addition to gas tax funds and funds provided by other infrastructure programs), incentives for transit users and research into innovative and safety improvements, among other improvements (FCM, 2007).
- Following the Johnson commission's inquiry into the de la Concorde overpass collapse, the Province of Quebec is taking back ownership of 4,281 bridges from the municipalities. The Province's goal is to bring 70% of the bridges up to acceptable levels of safety and serviceability by 2012, and 80% by 2022. To ensure that these objectives are met, $100 million will be spent annually for four years (2008-2012) (Dougherty, 2008).
- Under the 2008 Federal budget, $500 million will be invested into public transit; the municipal Gas Tax Fund will become a permanent source of funding for municipalities, which would reach $2 million by 2009-2010; and $10 million will be spent over a two year period to help clean up and repair small harbors, which will then be divested to municipalities (Department of Finance Canada, 2008).

While many of these actions are positive, the Canadian Union of Public Employees (CUPE) has evaluated some of the flaws associated with each of the 2008 budget allocations:

- The funds transferred to the municipalities from the Gas Tax Fund are not indexed to inflation or population growth. Therefore, the value of these funds will decrease by about 3% a year;
- Most of the $500 million allocated to transit systems in Canada are already allocated to the large municipalities – Montreal, Toronto and Vancouver – while smaller municipalities are struggling to meet their transit needs;
- While the Government is providing funding for improvements of small harbors prior to leaving these to the control of municipalities, they are not providing the assistance for their future upkeep, only leaving communities with an increased financial burden;
- Finally, a long standing demand of transfer of 1% of the GST to the municipalities for their infrastructure needs was not satisfied, but the Conservative Government chose to cut the GST instead. Transferring the 1% would have provided the municipalities with $6 billion annually (CUPE, 2008).

Further review of the 2008 budget and recent government initiatives, particularly the latest $33 billion Building Canada Fund, its benefits and shortfalls are presented in Chapter 5.

4.4 Industry

*4.4.1. **Deferred Maintenance***

On June 16, 2007 the Montreal Gazette published an article entitled "*Design, Build, Forget: A Flawed Formula*", in which Professor Saeed Mirza of the Department of Civil Engineering and Applied Mechanics at McGill University assessed some of the most deteriorated bridges and overpasses on the Island of Montreal. He discusses how, what he refers to as "*Design, Build and Forget"*, best represents the current mind-set in civil engineering practice. As stated by

Professor Mirza, “Maintenance? They do it. But if the government has a financial crunch, a budgetary crisis, maintenance is deferred” (Marsden, 2007). Not only is this way of thinking preventing a shift towards more sustainable practices, but it has also contributed to the current infrastructure crisis. With little or no consideration for the future upkeep of an asset at the initial planning stages of a new project, engineers and infrastructure management are failing to provide future generations with the tools and resources needed to better manage their assets. Instead, assets are simply being “passed on” to future generations often with high levels of deterioration that cannot simply be eliminated through maintenance or minor repairs, but which require elaborate repairs or some form of rehabilitation, at much higher costs than the costs that would have been needed if routine maintenance had been carried out.

This current mentality must change to one of – *design, build and <u>maintain</u>* – however, it is clear that there are inconsistencies in the way municipalities and other organizations plan for routine maintenance of infrastructure systems, and generally planning for maintenance is neglected altogether. It is recommended by federal governments and private agencies in North America, including the National Association of College and University Business Officers (NACUBO), the National Research Council of the USA (NRC USA) and the Civil Engineering Research Foundation (CERF) of the American Society of Civil Engineers (ASCE) that annual sustainable funding levels for maintenance should be between 2% and 4% of the current replacement value of an infrastructure asset (Vanier and Rahman, 2004). Figure 4.2 illustrates the effects that 0%, 1%, 1.5% and 2% maintenance levels will have on the infrastructure’s service life and quality of service (i.e., performance levels). For example, the ‘2% maintenance’ curve demonstrates that if the minimum recommended investment of 2% of the facility cost is reserved to provide for routine maintenance of the facility throughout its intended service life, the facility will operate at the minimum required service levels throughout this intended period of time. However, if no funds are dedicated to maintenance (‘0% maintenance’ curve), the facility will reach unacceptable levels of safety and serviceability (lower than the minimum acceptable quality level) long before the end of its service life. Depending on the facility in question, these unacceptable levels may be attained long before its design mid-service life. Therefore, regular maintenance would ensure that service levels are maintained at the required levels throughout the facility service life.

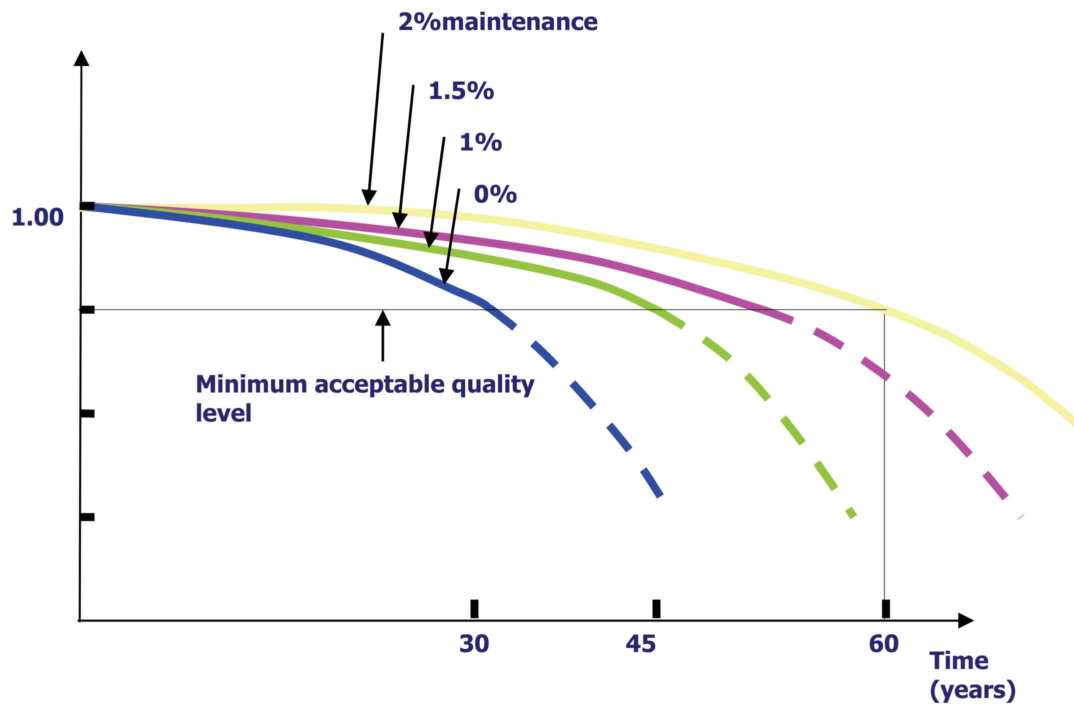

Figure 4.2 Qualitative performance curves showing the impact of different levels of maintenance on the infrastructure's useful life and quality level (Mirza, 2006).

In the 2004 NRC *Survey on Municipal Infrastructure Assets*, the municipalities were asked to specify their current and desired levels of maintenance expenditures, by specifying their annual maintenance expenditures as percentages of the replacement value of their assets. Figure 4.3 presents partial results of this survey; the responding municipalities' actual levels of investment are compared to their desired levels of investment. The main findings presented in Figure 4.3 suggest that:

- A majority of the responding municipalities (26%) spent less than 1.0% of the replacement value of the asset on maintenance;
- However, fewest municipalities (approximately 2.5%) claimed that a level of investment of ‘less than 1.0%’ was their desired level of investment;
- An alarming 21% of respondents were not even aware of their actual levels of investment;
- Therefore, together, almost half of the respondents (47%) demonstrated that little importance is placed on annual maintenance expenditures in their municipalities, as investment levels for maintenance are either ‘unknown’ or below a ‘1.0% investment’ level.

Another objective of the survey was to determine if the municipalities were aware of the recommended funding levels (between 2% and 4%). The main findings follow:

- 29 respondents (44%) were not aware of the recommendations;
- 15 respondents (23%) were vaguely familiar with the recommendations; and
- 22 respondents (33%) were aware of the recommendations.

The 22 municipalities who responded that they were aware of the recommended maintenance funding levels were asked to indicate what they thought was the recommended expenditure on maintenance. Only eight of these municipalities indicated what they thought the recommended figure was, and seven of the eight figures were correctly within the 2% and 4% range (Vanier and Rahman, 2004).

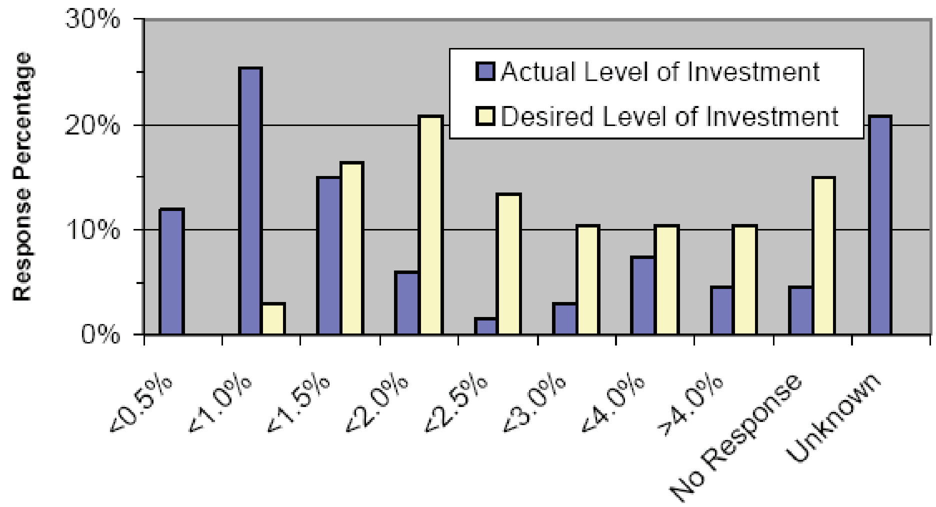

Figure 4.3 Actual versus desired maintenance funding levels of 66 Canadian municipalities (Vanier and Rahman, 2004).

*4.4.2. **Asset Condition and Worth***

The following example of water and wastewater systems should clearly highlight the difficulty in accurately ascertaining the areas of concern, as the exact state or, in some cases the existence of underground infrastructure in some districts are unknown. It is actually not surprising to find older pipes in these municipalities, made of cellulose fibre impregnated with tar, ceramic or even wood. This is particularly the case in older municipalities, which without a complete inventory of their underground infrastructure lack the information needed to perform a proper assessment of their municipal water and sewage infrastructure needs.

The most common ways of rating a water supply system include recording the number of breaks per year, per 100 km of pipe length. Presently, the Canadian average is approximately 20 breaks/100km/year (Sipos, 2006). Another rating method consists of recording the amount of water lost through leaking pipes. Loses between 5 and 10% are considered good, 15 and 25% are average and more than 30% signifies that the system is faulty (Siblin, 1999). However, again, without a complete national inventory of the underground infrastructure, one cannot accurately generalize the state of the underground infrastructure across Canada from the results of these condition assessment techniques. It is clear that even with responses from an infrastructure survey or a report card (which constitutes the third method of tracking an infrastructure asset's state of health) one cannot determine the exact needs in a scientific manner, given the subjectivity of the person responding to the survey and the varying condition assessment techniques used in each municipality.

The uncertainties related to the existence and, therefore, the condition of many assets include the lack of knowledge of the age of many assets, their remaining useful service life, their worth and, more generally, the value of a municipality's infrastructure stock. These uncertainties are confirmed and presented in Figure 4.4, which shows the municipalities' confidence levels in the responses provided in the 2004 NRC *Survey on Municipal Infrastructure Assets*. For example, when the municipalities were asked to give the remaining useful service life for different infrastructure assets, no municipality responded that they were "very confident" with their response, but rather a majority (approximately 56%) said that they were "somewhat confident". Similarly, less than 5% of respondents felt "very confident" with their responses regarding the condition of their assets. A majority (approximately 63%) said they were "somewhat confident". Confidence levels were slightly higher for other questions, such as that concerning the municipalities' infrastructure stock, however, while 55% felt "confident" of the infrastructure assets they claimed to own, only 12% were "very confident".

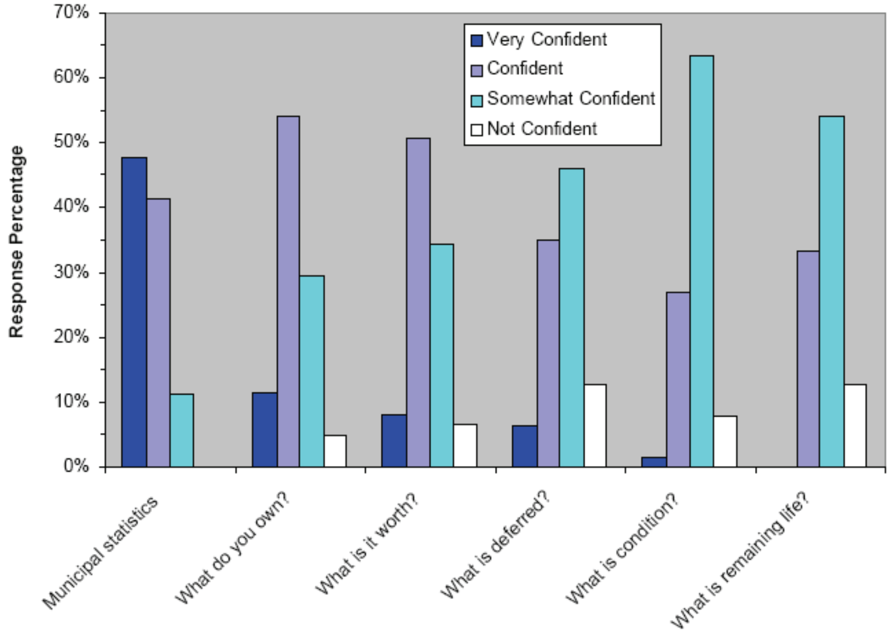

Figure 4.4 Municipalities' confidence levels for responses provided to the 2004 NRC *Survey on Municipal Infrastructure Assets* (Vanier and Rahman, 2004).

4.5 Academia

At a time when professionals, the public and politicians are aware or increasingly realizing that an infrastructure crisis prevails on the society, it is imperative that new graduates entering the areas of public works are adequately trained to accept the new challenges posed by the infrastructure crisis. While the previous sections suggest that professionals and politicians acknowledge the current issues and remain abreast of the ways of mitigating these issues, it is vital that the academic institutions remain at the forefront of the societal issues and new needs. For example, as the world is undergoing a new environmental movement, some Universities are only now beginning to integrate courses on sustainability and climate change into the civil engineering curricula – many have yet to make these topics a fundamental part of a civil engineer's development. This implementation should be made quickly so that new graduates can effectively deal with these issues. Most existing civil engineering programs should also begin to shift from one centered on design of new facilities, to one that places equal importance on educating students on maintenance and renewal techniques. There is an urgent need for these activities, and they must receive an increased priority in the future.

The universities must establish the tools and resources needed to establish courses dealing with the maintenance and upgrading of infrastructure, as well as courses on sustainable asset management and financing. The students should be trained to perform the condition assessments and ratings, inventory maintenance and management of the infrastructure facilities.

Table 4.1 presents a partial list of North American organizations who deal with various areas of infrastructure, from transportation systems, pavement and water supply infrastructures, to bodies who deal with all infrastructure categories. In most cases, these groups consist of professional organizations who lobby the government for funding and other important needs related to infrastructure, promote sharing of knowledge, ideas and best practices amongst professionals in the field, promote and ensure research and development in key areas, act as a central source of communication between professionals and the public for discussion of issues related to public works, etc. This partial list is meant to highlight the considerable research and development being carried out in this area. What is lacking is support and resources from decision makers, who should reconsider the role of some of the listed organizations. Efforts should be made to allow experts at Infrastructure Canada to help government bodies in making informed decisions when it comes to infrastructure planning, policy development, etc.

Table 4.1 Partial list of North American infrastructure organizations and their primary objectives.

Infrastructure Organization	Objectives
Infrastructure Canada www.infrastructure.gc.ca	▪ Build/communicate knowledge; connect researchers; help decision-makers; work with the Federal, Provincial and Territorial governments to establish needs and priorities; fund projects of national importance under government programs, etc.
Ontario Good Roads Association www.ogra.org/	▪ Advocacy, policy analysis; education and training; leadership in the area of infrastructure asset management; develop plans, programs and partnerships for service delivery in the area of transportation and public works
Sustainable Infrastructure Society www.greenbc.org	▪ Development and application of tools and resources needed for the development of adequate management, finance and operations to be used by water suppliers and other organizations who service communities with other infrastructure systems, in British Columbia
Transportation Association of Canada http://www.tac-atc.ca/	▪ Forum for the exchange of best practices, technical guidelines and ideas; promotion of best practices, safety, efficiency, environmentally-sound and financially sustainable services
Canadian Society for Civil Engineering http://www.csce.ca	▪ Promotes development and exchange of professional knowledge in all areas of civil engineering; maintain high standards of practice across Canada
American Society of Civil Engineers http://www.asce.org/asce.cfm	▪ Promotes development and exchange of professional knowledge in all areas of civil engineering; maintain high standards of practice across the U.S.
Amercian Public Works Association http://www.apwa.net/	▪ Educational and professional association; members include public agencies, private sector companies, etc; forum for public works professionals to exchange ideas, discuss public works issues; promote professional excellence; promote public awareness
American Concrete Pavement Association http://www.pavement.com/	▪ National technical initiatives (e.g., training and education programs to share best practices); promotion of concrete pavements through publications; advocating legislation that promotes adequate financing; influence legislative actions based on environmental concerns; recognition of outstanding work through awards programs; public relations – targeting decision makers in the area of transportation

American Public Transportation Association http://www.apta.com/contact/	▪ Advocacy, innovation and information sharing; represent transit agencies, public and private organizations, state departments of transportation, etc.;
American Water Works Association www.awwa.org	▪ Organization of water supply professionals; knowledge/information sharing; advocacy to improve water supply infrastructure and water quality

CHAPTER 5

FEDERAL GOVERNMENT PROGRAMS

5.1 Introduction

The federal government has developed some programs aimed at amelioration of the deteriorated infrastructure in Canada, with the improvement often occurring as a result of other desired objectives, such as job creation and better access to resources. To a lesser extent, the programs aimed explicitly at infrastructure improvements have also been implemented. Table D.1 in *Appendix D* summarizes the investments, objectives, and main outcomes of some of the major programs, acts and bills which have contributed to the shaping and renewal of infrastructure in Canada within the last century. Earlier programs were integral to facilitating national trade and travel across Canada, by linking the provinces and major cities with rail and highway systems, while later programs were primarily focused on ameliorating sanitation and reducing unemployment rates. More recently, programs have been directed towards improving the condition of infrastructure, encouraging private investment and promoting "green" practices.

Among these programs is the 1993 *Federal Infrastructure Works Program*, which was aimed at upgrading municipal infrastructure by investing in local communities. More precisely, the program was aimed at improving the state of the economy by investing in short-and long-term employment creation in local communities, in the area of infrastructure. A part of the 1996 FCM-McGill Survey was assigned to measuring the success of the $6 billion *Federal Infrastructure Works Program*. The municipalities questioned were asked to indicate and comment on the following:

- Facilities funded or improved by the program;
- Projects, if any, funded by the program;
- Whether the program funded some of the more important projects in their municipality;

- The amount of money allocated to their municipality by the program;
- If the municipality cost-shared a program that they felt was important; and
- The effectiveness of the program in improving the state of municipal infrastructure.

The perceived success of this program is illustrated by the positive response from 82% of the respondents, confirming that the program helped fund many major projects in their municipalities, the other 18% disagreeing or feeling unsure about whether the program led to any improvements. Moreover, the general consensus was that the program helped improve the state of infrastructure in Canada. However, 60% of the funds allocated to the municipalities under the *Federal Infrastructure Works Program* were used for projects involving new construction (Siddiqui, 1997). Therefore, while the municipalities stated that the program helped fund major projects in their municipalities, the program failed to meet its initial objectives of improving the condition of the existing deteriorated infrastructure.

Approximately 12,000 projects were funded under this program and about 10,000 jobs were created as a result (Government of Newfoundland and Labrador, 1997). Therefore, while employment creation was successful and communities were benefiting from the construction of new facilities, little was done to eliminate the backlog of deteriorated infrastructure. Consequently, the five year program had an immediate positive impact, but lacked a more sustainable approach to improving existing facilities before the end of its duration. Many of the programs listed in Table E.1 suffer from a similar lack of foresight.

5.2 Learning from Past Mistakes

Federal programs such as the *Canada Highway Act* (1919-1928) and the *Trans-Canada Highway Act* (1949-1971) have had a huge impact on the lives of Canadians, uniting Canadians and facilitating the transport of goods across the country. These programs can be considered among the most successful infrastructure-related government initiatives; other programs can be criticized for poor planning and investment decision-making. Although less successful, such programs can help to improve formulation of future programs that stem from safety-and sustainability considerations, with optimal allocation of funds and catering to long-term objectives.

5.2.1. ***Finding New Motivations***

The 1930 *Unemployment Relief Act*, the 1957 *Roads to Resources Program*, the 1963 *Municipal Development and Loan Fund*, the 1977 *Atlantic Provinces Primary Highway Strengthening/Improvement Program*, the 1982 *Employment Creation Grants and Contributions Program* and the 1993 *Federal Infrastructure Works Program* all share the objectives of increasing economic growth and reducing unemployment through public works projects. These programs show that investing in public works has been an effective way of improving the economy throughout the past century. Unfortunately, short-term economic gains have driven these programs more often than the needs to increase safety, improve the environment, and shift to more sustainable construction practices and long-term private investment.

The program objectives listed in Table E.1 show that infrastructure has commonly been upgraded as a result of wanting to improve employment opportunities for Canadians. Deterioration of existing infrastructure and the resulting tragedies clearly necessitate the need to rethink project objectives and focus on achievement of safety standards, with economic improvements becoming the desirable by-products. Such a shift is desirable from a political perspective, since Canadians would feel reassured that something is being done to ensure their safety at a time when crumbling infrastructure is a popular news item; tragic events are recurring and as a result, lives are being lost unnecessarily.

Table E.1 illustrates that the 1919 *Canada Highway Act*, the 2001 *Strategic Highway Infrastructure Program* and the 2001 *Canada Strategic Infrastructure Fund*, are a few of the major initiatives undertaken to improve infrastructure planning and management. These programs had the objectives of achieving more uniform road standards, improving transportation planning, encouraging funding partnerships and meeting climate change and sustainable development needs. Improving maintenance procedures, ameliorating the planning involved in infrastructure projects and developing better construction practices to account for climate change and sustainability, should be the motivations behind any future program.

5.2.2. ***Funding Allocations***

Population has been the main criterion to allocate funds for projects and programs in the past, because it is used as a rough measure of the needs of the provinces, territories and municipalities. A larger portion of funds is allocated to the most populated provinces and municipalities, which generally contribute the most to the economy and to improving Canada's image as a developed and competitive country. Therefore, the need to improve the economy and consequently the standard of living by improving municipal infrastructure in more populated areas is often considered a priority. The use of population as a basis for allocating funds for infrastructure cannot be rationalized. Larger cities are often in greater need of infrastructure renewal due to greater use and earlier construction of these assets, resulting in greater wear and tear. Also, these areas frequently need technological upgrades, such as intelligent transportation system technologies to reduce congestion and improve transportation systems, to remain competitive.

While population remains relevant, there are other, more relevant criteria which should be used increasingly by investment planners when prioritizing and allocating funds for infrastructure projects. However, audits of past programs have revealed that the information provided to investment planners is often inadequate for appropriately allocating funds.

The deterioration and primarily the inadequate design of the 115-km stretch of the Trans-Canada Highway between Gull Lake, Saskatchewan and the Alberta border has been the cause of over 900 accidents and 26 deaths between 1988 and 1998. This is but one of many sections of the Trans-Canada Highway across Canada that is described as "dangerous" by the Canadian Automobile

Association. However, an audit performed by the Office of the Auditor General of Canada (OAG), revealed that Transport Canada does not consider the safety rating of road segments when requesting funding, or approval for future programs (CBC, June 5 2007).

In Chapter 25 of a December 1998 report by the OAG: *Transport Canada – Investment in Highways*, deficiencies in planning for future highway expenditures are described. These deficiencies lie in the lack of accurate information provided to government planners, which led to inappropriate allocation of funds. The report states that “Transport Canada collects information from the provinces on road accidents and incidents, but generally uses it to compile statistics on vehicle safety and to summarize key statistics on incidents for its annual reporting”, and not to prioritize road works (Ruta et al, 1998). The provincial and municipal governments and concerned organizations such as the Canadian Automobile Association do have information pertaining to dangerous zones within the highway system, which can be used in any decision making for future investments. However, Transport Canada does not take advantage of this type of information and, therefore, it is not provided to federal government officials before the programs are approved.

Part of the *Highway Improvement Program* that ran between 1993 and 1998, was among other programs analyzed in the OAG’s report. Again, the report indicated the main shortcomings of the information provided to planners by Transport Canada. Firstly, the funding requested by Transport Canada to upgrade roads to acceptable levels was inappropriate for the funding allocations specified. In other words, Transport Canada claimed that roads were below the minimum national standards, but the funds requested to improve the highway system were more appropriate for meeting new level-of-service and proposed design requirements, which cost considerably more than the upgrades and maintenance needed to meet the national standards. The OAG also states that in the past, Transport Canada claimed to use “minimum national standards” to refer to actual minimum national standards, but also to refer to the proposed design and level-of-service improvements (Ruta et al, 1998).

Funding was proposed in 1997 to upgrade segments of the National Highway System that were initially recorded as being "acceptably smooth" and "over the acceptable engineering standards for surface roughness" – information that was obviously not provided to investment planners. Moreover, it was found that funds were being allocated to improve stretches of highway that already had funds approved for them under the same program. As a result, the Auditor General expressed the concern that allocated funds may have been used to meet cost overruns, rather than to achieve new program objectives (Ruta et al, 1998). In this case, scarce funding history has placed a barrier on successfully classifying priorities. In all cases, unclear and ineffective condition assessment methods; clearly lack the relevant information pertaining to the infrastructure condition has led to poor investment decisions.

5.2.3. ***Long-Term Objectives***

The duration of each of the programs listed in Table E.1 reveals the short-term commitment of the federal government to improving the state of infrastructure. Throughout the 1950's, 60's and 70's, programs were of a longer duration than those created today. Examples include the *Trans-Canada Highway Act* (1949-1971), the *Sewage Treatment Program* (1961-1974) and the *Road to Resources Program* (1957-1975). One can notice that beginning in the mid-1970s, the majority of the programs created were of a shorter duration. Among the shortest programs are the most recent, the *Canada Infrastructure Works Program* (1994-1999) and the *Infrastructure Canada Program* (2000-2007), lasting six and seven years, respectively. The latter two programs are also among the programs that are aimed at improving all categories of infrastructure in all provinces and territories. In comparison to the province-and infrastructure-specific *Newfoundland Transportation Initiative* (1987-2003) and the *Yellowhead Highway Improvement Program* (1987-1992), the six or seven year lifespan of the recent two nationwide programs hardly seems adequate.

Most of the programs tend to be focused on implementing immediate changes, with little consideration for sustained long-term improvement. Part of the problem lies in the country's reliance on federal grants and contributions, both forms of transfer payments, to finance the local infrastructure. The Treasury Board's June 2000 update of the *Policy on Transfer Payments* included "a requirement for the renewal of terms and conditions of programs within five years, unless otherwise approved by the Treasury Board" (Neville, 2000). The Treasury Board is responsible for overseeing financial management functions in departments and agencies, and of approving regulations. To gain approval by the Treasury Board, the department seeking to renew the terms and conditions of a program for an extended period must conduct a formal evaluation of the program and complete a report on the effectiveness of the program. Otherwise, with federal contribution programs not able to exceed five years without special approval, providing assistance to the provinces/territories and the municipalities over a longer term becomes a more difficult fragmented task.

The broader scope and shorter timeframe of some programs, such as the *Canada Infrastructure Works Program* and the *Infrastructure Canada Program* poses the question of clarity of the program objectives. Although the main objectives and outcomes of each project are summarized in Table E.1, the lack of more detailed information pertaining to program failures makes it difficult to assess whether most program objectives have been met. However, exceptions do exist and will be examined in the following paragraphs.

The 1963 *Municipal Development and Loan Fund* was created to fund municipal capital works programs aimed at creating employment. In total, $400 million or 2,429 loans were approved for 1,262 municipalities to upgrade water and sewer systems, schools, transportation systems, civic administration buildings and other recreational and public facilities. A review of the available literature shows that the Fund was allocated based on the community population. While the Fund did generate employment, particularly in the construction industry, it could have generated many more jobs, if the funds were allocated based on unemployment rates, given that the main objective was to create employment (Infrastructure Canada, June 7 2007). Therefore, while the program objective of creating employment was defined, the program did not meet the objectives to its full potential because they were not properly followed through. Furthermore, this program confirms that inefficiencies do exist when funds are allocated for certain programs, based on community population.

5.2.4. ***Future Needs***

Based on the successes and downfalls of the past and currently active government programs, the following recommendations are proposed for the improvement of future initiatives:

- Public safety should prevail, above all other motives, when defining program objectives. Meeting environmental standards and climate change objectives should be included in the scope of all programs.
- Program objectives should be clearly defined prior to the allocation of funds. On a large scale, population and unemployment rate can be the basis for the distribution of funds among the provinces and territories, depending on program goals. When defining more specific project objectives within the provinces and territories, infrastructure that poses a danger to the users should be assigned a higher priority and it must be funded and implemented first.
- Condition assessments of infrastructure facilities should be standardized nationwide to develop infrastructure priorities. This assessment should include a standard scale where infrastructure can be categorized based on its safety and the risk to the public.
- Federal investment planners should be given the pertinent information necessary for prioritizing projects and allocating funds. Information provided should include details of the facility's condition, its safety level, and history of funds that have been previously allocated to improving the facility, along with a list of the repairs and improvements made.
- Although program objectives should focus on improving the state of the infrastructure, they should focus equally on improving infrastructure-related practices. Specifically, some programs should be designated to improving maintenance standards, improving/standardizing condition assessment

techniques and developing a national inventory database. Funds should also be designated for training infrastructure management personnel and educating them on modern practices.

Finally, recommending an ideal timeframe for a federal program depends on the nature of the program, the influence of other policies and the exceptions, listed under these policies (e.g., the *Policy on Transfer Payments*).

The 1994 *Canada Infrastructure Works Program*, for example, was created to promote the development and the maintenance of various types of infrastructure: roads, bridges, water/sewer systems and other public buildings. While upgrading each of these types of infrastructure is urgently needed in all parts of Canada, it is also a need that cannot be met within a six year timeframe. The *Canada Infrastructure Works Program* and many others are needed to eliminate the infrastructure crisis one step at a time. However, the improvements brought about during the program duration will vanish quickly if the infrastructure is not properly maintained.

The *Trans-Canada Highway Act* is another example of an initiative that has benefited Canadians tremendously, by improving the country's competitiveness and standard of living. This Act has had one of the greatest outcomes in Canadian history: the world's largest national highway (7,821 km). However, the lack of specifications pertaining to future upkeep has also been a downfall. New branches have been added to the highway ever since its construction was completed in 1970, but maintenance and improvements on certain sections of the highway that needed immediate attention were deferred due to lack of funding from the federal government. Unfortunately, as mentioned above, many accidents have occurred and lives lost as a consequence.

5.3 The $33 Building Canada Plan

The Federal Government announced its latest infrastructure program in 2007, the $33 billion *Building Canada Plan*, which is to run between 2007 and 2014. Though the program is claimed to be the first of its kind, with such a high investment, it should be noted that only $16 billion is new funding (Department of

Finance Canada, 2007), the rest having been pledged by the previous Liberal Government. Table 5.1 gives the breakdown of funds that will be allocated under the *Building Canada Plan*. While it is refreshing and reassuring to see a program initiated with the overall objective of improving the state of infrastructure across the country, there are some shortfalls in the program. This becomes clearer when each respective fund or component in the plan is further analyzed. Details of each fund or component within the $33 billion plan are presented in Table 5.1.

Table 5.1 Breakdown of the $33B Building Canada Plan (Government of Canada, 2007).

Municipal GST Rebate ▪ Rebate has increased from 57% to 100% ▪ Fund the maintenance and upgrading of existing infrastructure assets ▪ Fund new infrastructure projects	**$5.8 B**
Gas Tax Fund ▪ Support environmentally sustainable municipal infrastructure – contribute to cleaner air, cleaner water, reduced GHG emissions ▪ Eligible project categories: public transit, water and wastewater infrastructure, community energy systems, solid waste management, local roads and bridges that enhance sustainability ▪ Funding for communities to adopt long-term planning – this will require the municipality to develop *Integrated Sustainability Plans*	**$11.8 B**
Building Canada Fund ▪ Priority funding categories include: NHS routes, drinking water, wastewater, public transit and green energy. ▪ Other projects: environmental projects (solid waste management), projects that support economic growth and development (short-line rail and short sea shipping, connectivity and broadband, tourism, regional and local airports) ▪ Development of safe and strong communities: disaster mitigation, culture, sport, local roads and bridges, etc. ▪ Support public infrastructure owned by provincial, territorial	**$8.8 B**

and municipal governments, and private industry in some cases. ▪ Funding will be allocated to the provinces and territories based on population ▪ All projects will be cost-shared – maximum federal contribution of 50%, except where the infrastructure is owned by the private sector – here the maximum contribution will be 25% ▪ Municipal infrastructure projects shared on one-third basis between federal, provincial and municipal governments	
Public-Private Partnerships Fund ▪ Support innovation projects that provide an alternative to government infrastructure procurement ▪ Expand infrastructure financing alternatives ▪ Provide incentives to the private sector ▪ Increase knowledge and expertise regarding alternative funding sources ▪ $25 million to establish a federal P3 office ▪ All projects seeking over $50 million in federal funds will be required to consider the P3 option	**$1.25 B**
Gateways and Border Crossings Fund ▪ Development of new gateway and corridor strategies ▪ Eligible projects include: NHS facilities impacted by increased trade flows, inter-modal connectors and facilities, international bridges and tunnels, rail/road grade separations, short-line rail, short-sea shipping, intelligent transportation systems ▪ $400 million to the construction of an access road for the new Windsor Detroit Crossing	**$2.1 B**
Asia-Pacific Gateway and Corridor Initiative ▪ A more specific entity of the Gateways and Border Crossings Fund	**$1.0 B**
Provincial-Territorial Base Funding ▪ Support the categories listed under the BCF ▪ Support the rehabilitation of infrastructure in these categories ▪ Federal funding cost-shared with provinces and territories	**$2.275 B**

▪ Ensure that smaller jurisdictions also benefit from this funding	
Total	**$33 B**

As can be seen, the first two components – the *Municipal GST Rebate* and the *Gas Tax Fund* - are the only two of the seven that will entirely be directed to the municipalities. Therefore, over half of the funding available under this program, or $17.6 billion, will be allocated to the municipalities. While this figure projects as a fair portion of the total fund going towards the municipalities, when this figure is spread out over the program's seven year duration, it is obvious that the approximate $2.5 billion that will be allocated to the municipalities is inadequate in comparison with the present $123.6 billion municipal deficit estimate. Furthermore, it is unclear as to whether this $2.5 billion per year will be used primarily to upgrade existing infrastructure assets, or it will be used to fund new projects. The $5.8 billion coming from the *Municipal GST Rebate* alone is said to be for both the upgrading of existing infrastructure and meeting new infrastructure needs. Again, if this figure is divided into the seven year period, it translates into less than $1 billion per year.

The $33 billion *Building Canada Plan* is a step in the right direction in terms of its motivations and goals. The plan is developed with the objective of improving the state of assets but unlike past programs, it is also meant to improve project planning and management through the following:

- The Public-Private Partnership Fund which will:
    - Improve and encourage the use of non-traditional financing alternatives;
    - Help establish a P3 office to facilitate the use of this funding alternative;
    - Establish requirements for project planners to turn to P3s as a funding alternative when seeking over $50 million in federal funds; and

- Help expand knowledge of the use of P3s and other viable financing alternatives.

- The Gas Tax Fund which will:
    - Help support sustainable infrastructure projects that will ensure reduced GHG emissions and contribute to the reduction of air and water pollution;
    - Encourage communities to focus on more long-term planning by developing *Integrated Sustainability Plans* to help achieve their long-term sustainability goals (Government of Canada, 2007).

While the latter points seem rather vague, the last point is also an example of an initiative with no mention of standardizing long-term planning techniques for the various municipalities. The municipalities will be required to report on their progress and use of this fund. No initiative is being taken, however, to help implement a long-term sustainability plan in each community. An ideal plan would help municipalities incorporate sustainable practices in their current management practices, such as life cycle analysis, routine maintenance and the required social and environmental impact analyses needed for the development of new sustainable infrastructure projects.

The new plan represents a significant effort by trying to incorporate long-term sustainable practices, consideration for the reduction of GHG emissions, and improved financing through alternative funding alternatives, and increased cost-sharing between the three levels of government. However, the program is deficient in not specifying appropriate allocation of funds, such as the lack of specifications pertaining to the allocations for existing and new infrastructure projects. Furthermore, the new initiative is frequently described as being one of a kind because of long-term goals. However, it is yet another infrastructure funding program with a specified duration and a specified fund. Provision of $33 billion over a seven-year period is clearly insufficient at a time when it is clear that the country is experiencing an infrastructure crisis and has to deal with a compounding deficit, while attempting to incorporate environmental and sustainability considerations and the impact of climate change, which have been recognized as crucial components of infrastructure planning only recently. The Government has yet to establish a sustained infrastructure fund that will provide continuous funding for the maintenance, repair and rehabilitation of existing infrastructure assets, and that will be complementary to future funding programs aimed at more specific projects and goals.

CHAPTER 6

SUSTAINABLE INFRASTRUCTURE-ASSET MANAGEMENT

6.1 Introduction

Various tools are needed to help practitioners achieve sustainable infrastructure planning and decision-making. Legislation and guidelines that regulate and encourage the use of a standardized asset management (AM) framework across Canada is urgently needed, if the infrastructure crisis is to be eliminated. Subsequently, successful implementation of the practices outlined in the guidelines can only be achieved with the assistance of a comprehensive AM information system. Some sources have presented state-of-the-art papers describing the benefits and the shortfalls of existing infrastructure-asset management systems (IAMS). The main challenges posed by available IAMSs are presented and the major needs in the area of infrastructure AM are summarized. This Chapter proposes an ideal IAMS that addresses the present shortfalls and needs. The recommended model supports facilitated implementation and maintenance of the IAMS.

A clearer understanding of the infrastructure deficit and the sub-deficits for the various asset types requires a detailed inventory of infrastructure assets, their existing condition and the risks posed by them to public safety, public and environmental health, and productivity, which are directly related to the economy, the international competitiveness of our country and the quality of life of Canadian citizens. These problems of funding constraints and the strong need to tackle the serious deterioration problems can be solved only with a strong national commitment and implementation of effective AM programs across Canada.

6.2 Why Asset Management?

Hudson et al (1997) define AM as “the systematic, coordinated planning and programming of investments or expenditures, design, construction, maintenance, operation, and in-service evaluation of physical facilities” and IAMS as “the operational package (methods, procedures, data, software, policies, decisions, etc.) that links and enables the carrying out of all activities involved in infrastructure management” (Hudson et al, 1997). Municipalities and organizations are increasingly adopting AM systems with increased privatization of infrastructure and public-private partnerships: AM helps “safeguard” the investments made by stakeholders. Also, as a result of the United States Government Accounting Standards Board (GASB) and the Canadian Public Sector Accounting and Auditing Board (PSAB) requirements that the value of tangible capital assets must be recorded within annual government statements (Falls et al, 2004).

Many software development companies are providing “asset management” systems with data storage capabilities and the ability to produce spreadsheets, charts/graphs and reports that facilitate analysis of this data for the common aspects of project planning (e.g., procurement, scheduling, etc). These vary between “general-purpose” and “asset-specific” software (Halfawy et al, 2006). The majority of the IAMSs support management operations, but they fail to encourage long-term planning, thereby maintaining the current mentality of “design, build and forget”, which must be changed to one of “design, build and maintain”.

The City of Edmonton is a leader in long-term planning approaches. Through its Office of Infrastructure (2000), the City of Edmonton maintains a complete inventory of all assets and financial data, and has developed a risk assessment methodology, a life cycle costing protocol, and a standardized condition rating scheme (based on letter grades) among other much needed tools. The latter has required that the City “translate” asset-specific condition ratings already employed by specific departments (e.g., the use of a Pavement Quality

Index by the Transportation and Streets Department), by defining conversions between ratings within a computer application. This is one way in which the City has addressed the challenge posed by the varying data, analysis and modeling needs for the different infrastructure categories/sub-categories (Cloake and Siu, 2002), providing for more integrated planning between the infrastructure categories.

6.3 Present Challenges

Between 2003 and 2007, the National Research Council's (NRC) Institute for Research in Construction (IRC) evaluated several existing AM and associated information systems (Table 6.1) and noted the following:

- Difficulties of developing AM techniques, and educating professionals and the public in the short-term (Vanier et al, 2005);
- Difficulties of integrating new information systems with existing databases, financial information management systems, etc. (Vanier and Danylo, 1998);
- A strong need to shift the mind-set of academia from the present focus on "design" to a much needed focus on "renewal" practices (Vanier et al, 2005);
- Sparse guidance available in implementing sustainable infrastructure strategies (Vanier et al, 2005);
- Lack of a central information source on AM (Vanier and Danylo, 1998);
- Lack of infrastructure AM codes, standards or guidelines (Vanier et al, 2005) (e.g., The InfraGuide, produced by the FCM, the NRC and Infrastructure Canada).

Specific needs include:

Economic

- Implementing life-cycle analysis and costing as standard, routine practices (Vanier et al, 2005);
- Including valuation and deprecation as key factors in the life-cycle analysis;

- Identifying sustainable funding levels to ensure routine maintenance for the different infrastructure types (Vanier et al, 2005).

Technical

- Developing deterioration models to assist in equitable project prioritization (Vanier et al, 2005);
- Adopting standard practices to evaluate the remaining service life of infrastructure assets (Vanier et al, 2005);
- Uniform standardization of condition assessment techniques and rating schemes for improved project prioritization (Vanier et al, 2005);
- Adopting objective condition assessment and condition rating techniques, to be compatible with clear, pre-defined management methodologies, defect condition ratings and measurement scales (PSAB, 2007); and
- Developing management information systems that facilitate integrated management of assets (Vanier et al, 2005).

Technological

- Encouraging the development of information systems by software companies working closely with professionals who work in the domain of municipal works to ensure the most comprehensive and satisfactory systems;
- Facilitating the continual maintenance and upgrading of management systems.

Others

- Ensuring the available funding and other resources necessary for implementation of IAMS;
- Incorporating existing and new environmental regulations;
- Adapting to the needs of climate change;
- Catering to urban and rural needs within one system;

Finally, there are associated social and political issues that pose many challenges. The Government must commit to a sustained program to address and mitigate all issues presented, and fund programs to develop legislation, information systems and implementation strategies to support these as standard management practices.

6.4 Asset Management on an International Scale

The Australian and the New Zealand Governments have shown strong commitments to IAMSs since the early 1990's, the AM guidelines and manuals, legislation and programs have, become widely accepted in both countries. Some highlights follow:

- The Australian National Audit Office (ANAO), the National Public Works Council Inc. and various State Government departments publish and maintain AM guidelines and manuals (Shah et al, 2004).
- Victoria, Tasmania, Queensland and Western Australia have all implemented AM improvement programs aimed at increasing the knowledge of council staff on the subject of AM. Such programs have focused on improving the understanding of asset and service level characterization, and methods of funding prioritization among many other topics (NSW DLG, 2006).
- In 2005, the Local Government (Financial Management and Rating) Amendment Act was passed by the South Australian Parliament, requiring that all councils "incorporate long-term financial plans and asset management plans in their strategic plans, establish audit committees, and consult with their communities on annual programs and budgets" (NSW DLG, 2006).
- Western Australia's Local Amendment Act (1995) requires that councils develop two year asset management plans for the future and that these be maintained and updated every two years. These future plans must be taken into consideration in preparing the council annual budgets (NSW DLG, 2006).
- New Zealand's Local Government Amendment Act (1996) requires that councils prepare long-term financial plans (10 years) and that these be reviewed every three years. In addition, the 2002 Amendment Act specifies that all local

governments develop and abide by the asset management practices within a long-term community plan. These include the requirements to identify assets, to identify the procedures that will be undertaken to maintain, renew and replace assets, and to identify the funding plans for these activities (NSW DLG, 2006).

Therefore, since the early 1990's, Australia and New Zealand have led the way in using sustainable decision- making tools, including development of AM guidelines, manuals, and related legislation and programs. Other countries have also been implementing IAMSs for some years, however, in many cases these systems are asset specific and lack the integration capabilities necessary for complete project prioritization at a national scale. For example, the U.S.'s Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) have worked closely together to provide state and local transportation agencies with the technical assistance and training needed to implement specific IAMSs, including the various Pavement Management Systems (PMS) and Bridge Management Systems (BMS).

The Australian literature reveals that, similar to the U.S., state manuals and information systems vary, making it difficult to co-ordinate management practices at the state and the national levels (PSAB, 2007). The latter highlights a major need in the development of an ideal IAMS for Canada: IAMSs should support the use of consistent AM practices and data recording between the provinces, territories and municipalities. For example, if one municipality groups sewer systems and stormwater systems in one classification, it is difficult to compare the needs of other municipalities who keep records of both asset types separate, which adds to the difficulty of adequately prioritizing the needs. One system that supports the implementation of standard practices would be ideal, but it would require that aspects of the system be customizable to account for varying demographics, environmental conditions and new regulations, population growth, activities/lifestyles, local needs, etc.

6.5 Existing AM Systems

Principal highlights of a representative sample of typical systems used in North America are summarized in Table 6.1. If these highlights are combined to form one system, the system's framework would consist of three main groups of features: software, management and technical. The first group comprises attractive features of the software itself, such as the characteristics of being web-based, GIS-based, easily integrated to other common applications, etc. (Column 1 in Table 6.1). The management features include those that support long-term planning and the ability to store AM protocols. The largest group is the last - the technical features – which enable all data modeling, analysis and reporting. The software features are generally common to all systems, while the management and, increasingly, the technical features are particular to only a few systems. Therefore, while some key components of IAMS are listed in Table 6.1, these aspects are limited to only a few systems, and therefore they benefit a few municipalities and organizations.

Two components in a typical framework proposed by Lemer (2000) are particularly lacking in North American systems: renewal engineering and capital investment strategy. It is important that future systems provide for distinction between the management of renewal projects and new construction. The 1993 $6 billion Federal Infrastructure Works Program was partly aimed at upgrading existing municipal infrastructure by investing in local communities and was partly used to create jobs in the area of municipal works to improve the state of the economy. At the end of the program, it was found that 60% of funds were utilized towards new construction, thereby not meeting a major project objective. There is an urgent need to maintain, rehabilitate and replace much of the existing crumbling infrastructure that poses a threat to public safety and productivity. Prioritizing renewal projects over new construction in many cases therefore represents another significant challenge. An IAMS that supports long-term forecasting and risk assessment of renewal versus new construction projects is urgently needed. The latter would sustain the much needed shift in the current focus of the academia and the industry on "design" to a focus on "renewal".

6.6 A Proposed AM System

A framework for an ideal IAMS, aimed at municipalities and organizations across Canada, is proposed in Figure 6.1. It is important that the system can be easily customized to incorporate the considerable local variations, and that some features be standardized. Furthermore, it is essential that such a program be developed, maintained, and managed by a central focus group, an interdisciplinary group of experts who would act as a central source of information for practitioners across Canada and who would be responsible for updating the system at regular intervals.

The system has been divided according to the three main system features presented earlier: software, management and technical. These have further been sub-divided into sub-features, modules (groups of data manipulation and analysis functions that are accessed through multiple views) (Halfawy et al, 2006) and sub-modules (multiple-view features, where functions are limited in comparison to those in a module). Each has been numbered, as a brief review of the usefulness and importance of each component of the proposed system follows.

Table 6.1 Main highlights of common North American IAMSs (data from Halfawy et al, 2006).

System Highlights	System	System Highlights	System
Web-based	▪ Synergen	Extensive modeling capabilities: ▪ asset valuation ▪ deferred maintenance ▪ remaining service life ▪ condition assessment ▪ rehabilitation and maintenance prioritization	▪ RIVA ▪ Infrastructure2000
GIS-based	▪ City Works (2005)	Extensive reporting capabilities	▪ MIMS
System contains its own GIS functionality	▪ Municipal Infrastructure Management System (MIMS)	Availability of pre-formatted reports	▪ MIMS
Ability to modify GIS viewing to show desired features	▪ MIMS	Contains standard structural condition ratings	▪ MIMS
Work orders and assets can be spatially linked to street addresses	▪ City Works (2005)	Production of deterioration curves	▪ Infrastructure2000
Browser-based Internet access to the asset geo-database	▪ City Works (2005)	Capability to compare funding scenarios based on pre-defined deterioration models	▪ Infrastructure2000

Table 6.1 (Continued)

System Highlights	System	System Highlights	System
Program installation on a server or hosted by the supplier	▪ Real-Time Asset Valuation Analysis (RIVA) (2005)	Models the impacts of various maintenance and rehabilitation project options on deferred maintenance	▪ RIVA
Interfaces with external applications (e.g., GIS systems, email, Supervisory Control and Automatic Data Acquisition Systems – SCADA)	▪ Synergen ▪ RIVA ▪ Hansen ▪ Harfan	Project prioritization based on various criteria: ▪ funding ▪ condition rating ▪ available renewal options ▪ remaining service life, etc	▪ Harfan ▪ Hansen
Possibility to email work order and service requests to personnel	▪ City Works (2005)	Models and formulas can be altered and their outputs are automatically changed	▪ RIVA
Includes a search engine	▪ Synergen ▪ MIMS	Supports asset valuation	▪ Hansen
Data import/export capabilities	▪ Synergen ▪ MIMS ▪ RIVA ▪ Hansen	Asset valuation based on integrated economic factors	▪ RIVA

Table 6.1 (Continued)

System Highlights	System	System Highlights	System
Capability to customize ▪ Asset classes ▪ Viewing options ▪ Schemas	▪ Synergen ▪ City Works (2005) ▪ RIVA	Deferred maintenance calculated based on pre-defined best practices	▪ RIVA
System design is flexible – therefore easily subject to change	▪ Harfan (2005)	Determines extent of deferred maintenance	▪ Hansen
Supports long-term planning	▪ RIVA ▪ Harfan	Generates event priority lists	▪ RIVA
Includes condition assessment protocols, but these can also be defined by the user	▪ Harfan	Estimated remaining service life	▪ Infrastructure2000

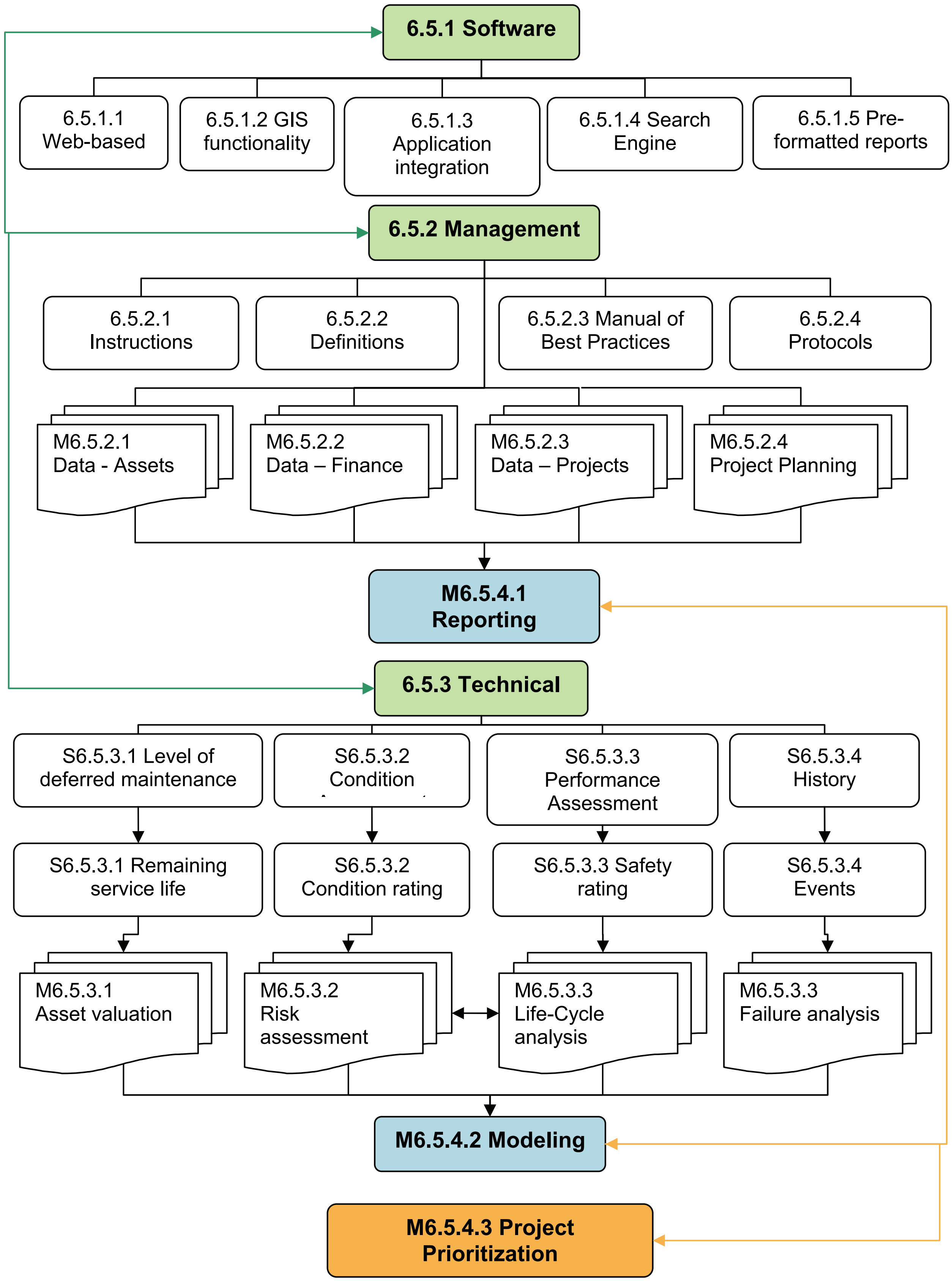

Figure 6.1 Proposed IAMS framework (M – Module, S – Sub-module).

6.6.1. ***Software***

6.6.1.1. Web-Based

- Economical and time-efficient: the system can be hosted/maintained by the supplier and managed/updated by the central focus group.
- Initial investment may be high, yet smaller municipalities and organizations in particular, do not have to worry about the time, costs and headaches associated with installing of the software on their servers.
- Internet access facilitates project management: designated personnel have access to the system at any time and place (e.g., in the field).
- Work assignments or other data can easily be e-mailed to clients or personnel.

6.6.1.2. GIS Functionality

- Spatial and non-spatial data is combined in one database, eliminating the need for data duplication or verification. One can simply place their cursor over a road-map and select the asset for which data is to be displayed, using different modules of information for this particular asset.
- Links street addresses to various assets for convenience of the administrators. For example, in the event of a watermain breakage, one can easily identify which addresses are serviced by the pipe, enabling quick identification of the households that must receive notifications and boil-water advisories (Halfawy et al, 2006).

6.6.1.3. Application Integration

- Import-export and interfacing capabilities with the most commonly used software supporting data spreadsheets, financing and other present management practices.
- Equipped for digital photo storage and interface capabilities with multimedia applications (e.g., Windows Media Player, QuickTime Player, etc.) that can support video storage for improved visual information sharing.

6.6.1.4. Search Engine

- Enables rapid searching for asset or project information that fulfills certain criteria (e.g., searching for all roads with a specified condition rating, which will help in transportation project prioritization).

6.6.1.5. Pre-Formatted Reports

- Ready-made and customizable report layouts assist in the standardization of practices.
- Ensures uniformity of data-keeping and modeling.

6.6.2. *Management*

6.6.2.1. Instructions

- Provides detailed instructions and "help" features, similar to those available in Microsoft Office.
- Useful for encouraging IAMS use and for training of new personnel.

6.6.2.2. Definitions

- Enables uniformity of definitions of terms. For example, infrastructure renewal projects are clearly classified as 'maintenance', 'repair', 'rehabilitation' or 'replacement' in the inventory system. These distinctions should clearly be defined and based on the extent of the asset's modification.
- The main infrastructure categories and sub-categories are clearly defined for accurate classification.

6.6.2.3. Manual of Best Practices

- Complements the IAMS, supporting standard practices.
- Must be maintained and updated with new protocols, legislations and best-practices.
- Available online through the IAMS, enabling easy access to all users and online updating by the central focus group, eliminating the need for installation of new software or the publication of new manuals.

6.6.2.4. Protocols

- The regular maintenance and updating of the protocol directory is essential given the dependence of subsequent modules on the defined protocols.
- All of the standardized practices, e.g., condition ratings, historical and financial records, and minimum specified service levels (engineering and environmental) are specified in this directory for consultation and guidance.

M6.5.2.1 Data – Assets

- Sections are labeled as physical attributes (age, materials, size, photos, videos, etc.), condition (i.e., assessment details), construction specifications (year, contractors and relevant contact information), upgrade specifications (year, type, details of contractor), etc.
- Pre-formatted data entry tables encourage and assist practitioners in keeping a detailed inventory of all assets, but are customizable.
- All data are spatially linked and easily accessed from a GIS map.
- Data may also be viewed from a list for convenience, with multiple viewing options (e.g., viewing of all infrastructure categories/sub-categories, specific categories, infrastructure networks, criteria-based viewing).

M6.5.2.2 Data – Finance

- Similar to the *Data – Assets* module: financial data consists of general infrastructure financial reports and budget history, but also data that was input in the asset valuation and life-cycle costing module and sub-module, respectively.
- Includes different views: full budget, operating expenditures and maintenance budget views; financial data by infrastructure type, sub-type, asset type, etc.; financial data by project; etc.

M6.5.2.3 Data – Projects

- Assists project managers in keeping abreast of project details (e.g., procurement and scheduling sub-modules).
- Can view upcoming projects by date, type, priority level, location, etc.

M6.5.2.4 Project planning

- Focuses on the preliminary phases of project planning, feasibility studies and tendering process.
- Considered a basis for the *Data – Projects* module.
- Through the system's email capability, the user is notified of upcoming projects (e.g., routine inspection and maintenance needed) and deadlines.

6.6.3. ***Technical***

S6.5.3.1 Level of deferred maintenance and remaining service life

- Methods of determining deferred maintenance exist: The RIVA model involves pre-defining best practices and measuring the level of deferred maintenance based on the extent for which the practices were followed (Halfawy et al, 2006), while the more accurate NACUBO model consists of ranking an asset with a facility condition index (FCI), equal to the cost of deferred maintenance divided by the capital replacement value (CRV). An FCI should normally remain below 0.15 (Vanier and Danylo, 1998). Other possible models should be investigated, though the last has been efficient for many municipalities.
- Based on the level of deferred maintenance and data from the asset valuation module, the remaining service life of the asset can be determined.

M6.5.3.1 Asset Valuation

- Comprises valuation procedures and spreadsheets for various asset types (more research is required in this area and in incorporating depreciation into this process).
- As in other modules comprising spreadsheets, formulas for automated calculation of values can be incorporated into the system and altered at any time by the central focus group (e.g., change inflation rates within formulas), which automatically changes existing values and data modules.

S6.5.3.2 Condition Assessment and Rating

- The best practices manual will include condition assessment techniques and standard condition ratings for each asset type. Protocols for condition rating are provided in the management framework.
- The City of Edmonton's rating scheme considers physical rating, demand/capacity and functionality - this can be used as an ideal example (Cloake and Siu, 2002).
- Data updates in the condition rating modules automatically generate changes in the level of risk posed by an asset on the society, environment, etc.

M6.5.3.2 Risk Assessment

- The risk of a system failure is based on probability and statistics related to the technical data.
- Considers the impact of such a failure on the society in terms of safety, health, productivity, the economy, the environment and international competitiveness.
- Evaluates the risks of the various projects and life-cycle assessments.

S6.5.3.3 Performance Assessment and Safety Rating

- Analysis of the asset's level of performance based on condition assessment and rating, present worth, public complaints (an inventory would be maintained here) and safety ratings, based on the number of accidents, deaths and illnesses caused by an asset's condition.

M6.5.3.3 Life-Cycle Analysis

- Must include life-cycle costing and risk analysis.
- An asset is analyzed from the preliminary phases of project planning to the decommissioning of the asset.
- Supports the definition of sustainable development. Future generations would not be left with a backlog of deterioration and an escalating infrastructure deficit if routine maintenance is specifically included for in the initial project planning phase.
- Research and information sharing for the development of associated protocols are needed.

S6.5.3.4 History and Events

- Includes detailed performance records of the assets when subjected to natural or man-made disasters over the course of its service life.
- Extreme weather patterns are recorded to help in evaluating the risk of associating infrastructure damage, or failure to one of these extreme events.
- The need for such a module will increase with the looming climate change.

M6.5.3.4 Failure Analysis

- Includes analysis and evaluation of the probable cause(s) of failure, along with the recommendations for improved risk mitigation.
- Recommendations can be used to improve the best practices manual and, consequently, the IAMS protocols.

6.6.4. ***Decision-Making Tools***

- Decision-making will be made simpler with the use of the reports, modeling and project prioritization modules.

M6.5.4.1 Reports

- Includes report templates: financial, technical, environmental, etc.
- Data may be drawn from the various modules for report formulation.

M6.5.4.2 Modeling

- Comprised within the 'technical' portion of the system's framework to enable forecasting, comparisons, or further analysis of the various assessments within the modules such as, risk, life-cycle performance and failure;
- Enables modeling of the impact of various renewal options on deferred maintenance renewal and new construction options on funds, society/business productivity, the environment, etc., of alternative funding allocations on deterioration, etc;
- Deterioration forecasts are modeled based on the present levels of deferred maintenance, minimum acceptable service levels, projected funding, increased use, etc.;
- The user is required to specify whether the data being modeled pertains to an existing asset, or a new structure, which in turn would present the user with appropriate modeling options and access to the relevant data. Upgrading the existing needs and keeping new needs separately will permit improved project prioritization.

M6.5.4.3 Project prioritization

- Is improved considerably because of the extensive inventory, and the report/analysis and modeling capabilities;
- Is based on all of the modules presented in this chapter;
- Priority lists can be generated automatically using sophisticated software.

6.7 Summary and Recommendations

An IAMS for municipalities and organizations in Canada should comprise standardized practices and customizable features that would improve project prioritization and related funding allocations at the national level. The development of best practices, a complementing manual and a supporting information system requires extensive work of an interdisciplinary group of professionals dealing with different areas of infrastructure management. These tools would provide municipalities and organizations with a structured approach to tackling their local infrastructure issues and associated deficits. Such a system would be more comprehensive than any current system because it comprises all of the modules necessary for the development of a detailed inventory of all assets and all management practices. This IAMS would also support the much needed shift to a ‘design, build and maintain’ philosophy, which is a more sustainable long-term infrastructure AM approach.

CHAPTER 7

FINANCING OF INFRASTRUCTURE

"Infrastructure policy should require the fair allocation of costs among all levels of government and users. Federal investment in public infrastructure has declined substantially in over the last three decades, so that state and local governments now spend nearly three times as much as their federal counterpart on infrastructure [...] A national infrastructure financing facility is needed to serve as the window through which states and localities may obtain financing or grants for specific projects. A federal investment vehicle of this kind would address many wasteful tendencies in infrastructure provision and redirect policy towards promoting overall returns on investment" (Dodd and Hagel, 2007).

7.1 Common Funding Mechanisms

The revised 2007 estimate of the municipal infrastructure deficit of $123.6 billion for upgrading needs and $115.2 billion for new needs has proven that investment in infrastructure has been highly insufficient (Mirza, 2007). Maintenance of Canada's infrastructure assets at acceptable levels of safety and serviceability has been neglected and, very often, new needs have been ignored due to insufficiency of funds. Considerable new investments must be made in infrastructure to support a superior quality of life for all Canadians. The three orders of government are beginning to feel this financial pressure, as is the public who fears the many possible negative consequences that the present state of infrastructure may pose. At this crucial time, it is essential to re-evaluate the way infrastructure has traditionally been financed and to begin to turn to more innovative and sustainable sources of financing. With innovative funding techniques, it is hoped that:

- More money will be diverted towards infrastructure needs;
- That more money will be available to finance not only maintenance and upgrading activities, but that sources will be available to promote and begin implementing initiatives to improve and standardize asset management practices across the country, including life-cycle costing and analysis; and
- That an initial significant investment will be made to establish infrastructure financing facilities as sustained funding sources, which will also promote permanent adoption of innovative funding practices, even in times of prosperity.

The traditional and most common infrastructure funding mechanisms are reviewed in Table 7.1, and the main advantages and disadvantages of each are outlined in Table 7.2.

Table 7.1 Review of traditional infrastructure funding mechanisms (information retrieved from Slack, 1996 unless otherwise noted)

Funding Mechanism	**Details**
Taxes	Property taxes, which can vary from one community to another make up the largest source of income for municipalities. ▪ General tax rates: revenues fund general expenditures ▪ Special rates: while applicable to all taxpayers, revenues are allocated to specific projects or purposes ▪ Local improvement charges (or special assessments): collected from properties who will benefit from a particular project or service in its vicinity ▪ Special area rates: in areas receiving a particular service
Special Finance Districts	An organized – governmental – autonomous entity (other than a municipality) that offers services (e.g. boards, authorities, commissions, etc.). Revenues come from user fees, property taxes, special assessments and provincial grants; depending on the type: ▪ Tax increment financing (TIF): Taxes increase with increased property value and these are used to

	pay for capital projects (improvements or new) ▪ Special benefit assessment: Taxes are collected from property owners that will benefit from the infrastructure, or service improvements ▪ Local improvement: Similar to the previous item, but in addition to taxes, debt financing is also used to pay for the infrastructure
User Fees	The user of the infrastructure is charged for its use. Fees go towards the operating costs of the facility or service. Different types of pricing exist: ▪ Marginal cost pricing: to ensure efficient allocation of funds and that the use of the infrastructure is not excessive, the price equals marginal cost ▪ Increasing block pricing: price increases or decreases with an increase or decrease in use, respectively. For example, with increasing water use, the charge per unit of water increases. The opposite is true. ▪ Decreasing block pricing: price decreases with increased use of a commodity. The opposite is true. ▪ Two-part tariffs: a monthly or annual fee that does not change with consumption, in addition to a flat rate per unit of consumption. (CMHC, 1992)
Bond Financing	The municipality issues bonds to finance the infrastructure. The bonds are secured with user fees or property taxes.
Development charges	The developer is charged for infrastructure that is needed as a result of a development or redevelopment – or growth.
Pure Privatization	A private company design, builds, owns, operates and finances the infrastructure
Public-Private Partnerships (P3)	A joint venture between the government and one or more private companies; costs, risks and income are shared depending on the partnership aggreement[1]
Borrowing	Also known as debt financing; municipalities borrow funds to pay for major capital projects and repay funds with operating revenues (e.g. property taxes, user fees)

[1] There exist different forms of public-private partnerships. These are described in Section 7.2.1.

Table 7.2 Advantages and disadvantages of common funding techniques (information retrieved from Slack, 1996 unless otherwise noted)

Advantages	Disadvantages
Property Tax	
▪ A "visible" tax: paid directly to the government by the taxpayer and projects/services financed by the tax are visible	▪ Capital projects are competing with other essential service (e.g. police, fire) for funding allocation ▪ Unfairness of commercial/industrial buildings paying higher property taxes, when they benefit from fewer services
Special Assessment and Local Improvement Charges	
▪ New or renewed infrastructure near a property increases the property's value	▪ Lengthy process: involved negotiations and lengthy paperwork
Special Area Rates	
▪ Land value capture taxes: increases property value, often without improvements to the property	▪ Difficult to estimate public expenditure and changes in property values
Special Financing Districts	
▪ Equality: the person paying/demanding for the improvement is benefiting from the improvement ▪ Long-term financing, as opposed to up-front payments ▪ Do not have to rely on revenues of local governments ▪ A way of targeting certain services to specific groups	▪ Limited to areas undergoing rapid growth ▪ Governmental fragmentation ▪ Public confusion due to possibly numerous agencies, authorities, etc.
Fees	
▪ Fees are linked to the use of the infrastructure, thereby maintaining adequate levels of serviceability ▪ More efficient use of resources and less "over-consumption" of services and facilities ▪ Reduce the demand for certain services (e.g. water and bridges/highways)	▪ Over-consumption, overuse and abuse of infrastructure and services provided ▪ Possible negative effect on consumer behavior (e.g. suburban sprawl or urbanization with tolls) ▪ Rarely reflects marginal costs, which is considered more efficient
Bond Financing	
▪ More effective for large municipalities that have a good bond rating and low interest rates, thereby attracting more investors	▪ Small communities typically have higher interest rates, because they are typically not rated (CMHC, 1992)

▪ Inversely related to interest rates: during periods when interest rates are high, short-term bonds are a better alternative than long-term debt financing (CMHC, 1992)	
Development Charges	
▪ Money is spent efficiently: new infrastructure is only built if there is a demand ▪ Equity is affected: some consumers may not be in a position to pay for the service (CMHC, 1992)	▪ Cover construction costs, but not maintenance costs (these are collected through user fees, or general revenues) ▪ Double taxation for new property owners (paying for new infrastructure with development charges and for existing infrastructure with property taxes) ▪ May limit growth in a community (CMHC, 1992)
Pure Privatization	
▪ Faster project completion ▪ Cost savings (idea that private firms are more cost-efficient than the public sector) ▪ Economic development ▪ The user pays for the service ▪ The private sector bears all risks (good for the public sector) (CMHC, 1992)	▪ Possible difficulty in acquiring initial financing ▪ The private sector bears all risks (risky for the public sector when considering the regulations that govern the private sector, for example environmental regulations, etc.) (CMHC, 1992)
Public-Private Partnerships (P3)	
▪ Take advantage of public funds; no need for up-front capital costs from government ▪ Use of tax benefits (which the public sector cannot use) by the private sector ▪ Use of private sector resources, skills and expertise	▪ Risk posed by depending on private sector; potential quality control problems ▪ Loss of control by the public sector ▪ Possible union problems ▪ Cutbacks in government jobs
Borrowing	
▪ Enjoy the benefits of new projects that are not always possible with existing funds ▪ Avoid large fluctuations in yearly tax rates ▪ Cost is spread over future beneficiaries	▪ Paying interest ▪ Revenues are not available for use other than for debt repayment ▪ The amount of debt can affect the municipality's credit rating – increasing capital costs

7.2 Innovative Financing Alternatives

*7.2.1. **Public-Private Partnerships***

Public-private partnerships or P3s were described in Table 7.1: they are joint ventures between the public sector and one or more private sector companies. P3s can take many forms; the main ones are briefly described in Table 7.2, as are the various risks and responsibilities shared by each party for each of the various types. The main benefit of a P3 is the ability to take advantage of what each party has to offer, whether it is funds or skills and expertise. Furthermore, there is greater opportunity to plan for one party's involvement with the asset maintenance costs throughout its life-cycle. Lastly, P3s can be used to finance the various infrastructure types, whereas financing through tolls or other user fees, for example, are better suited for particular infrastructure types.

While P3s are increasingly being considered in Canada, they have not yet become common practice, as they have in many other countries, especially in Europe. The Confederation Bridge spanning between New Brunswick and Prince Edward Island is one example of a recent Canadian P3 project, of the form of Design-Build-Operate-Transfer (DBOT). The bridge was designed and built by a private international firm, which will also operate and maintain the bridge for a 35-year period with revenues collected from the tolls during that period. Initial capital for the project was provided by the public sector: a New Brunswick Crown Corporation funded the project by issuing bonds and the Government of Canada will continue to secure these bonds with annual payments of $41.9 million over the 35 year period, after which the bridge will then be transferred to the Canadian Government (Loxley, 1999).

As described in Section 5.3 – *The $33 billion Building Canada Plan*, $1.25 billion will be spent over the next seven years to help promote increased use of P3s as a funding technique in Canada. This Public-Private Partnership Fund will also aim to establish a federal P3 office to support and provide the knowledge and expertise needed to facilitate the integration of this funding technique into municipalities and private companies who have had little or no experience with this type of funding. The Netherlands similarly uses a P3 Knowledge Centre, where advisers are available to help guide government agencies who are interested in this alternative funding source (Grimsey and Lewis, 2004).

Table 7.3 Forms of public-private partnerships (Slack, 1996).

Public-Private Partnership – Type	**Parties' Responsibilities**	
	Public	**Private**
Operate	▪ Capital costs	▪ Facility operation (for a fee)
Lease/Purchase and Operate	▪ Initial ownership	▪ Purchases/leases facility from the public ▪ Facility operation ▪ Charges user fees
Lease/Purchase, Build and Operate	▪ Initial ownership	▪ Same as previous, plus builds/develops new facility or enlarges/renovates existing facility
Build (turnkey partnership)	▪ Gives specifications for the facility's construction ▪ Assumes ownership after construction	▪ Is paid a fixed fee to build the facility according to public sector specifications ▪ Turns over facility to public sector after construction
BOT (Build, Operate, Transfer)	▪ Assumes ownership after construction and after private sector operated the facility for a specified period	▪ Develops and builds required facility ▪ Facility operation for specified time period ▪ Transfers facility back to government
Build and Operate	▪ Regulates and controls operation	▪ Capital financing ▪ Construction and operation
Build and Transfer	▪ Assumes ownership after construction	▪ Construction ▪ Transfers ownership to the public sector

7.2.1.1. Shadow Tolling

In the United Kingdom, a concept called "shadow tolling" has been used for numerous road construction projects. Here a private company is responsible for the design, construction, financing and operation of a road/highway. The public sector reclaims ownership of the road/highway between a pre-defined 15-25 year period. As the name implies, users are not expected to pay a toll, but instead, the government pays a "shadow toll" or a sum equivalent to what would have been generated with the use of tolls that is dependent on traffic volume. This method is therefore favored by the public, who are not expected to pay tolls, takes advantage of expertise from the private sector for all aspects of the project, and helps the local governments (and therefore other orders of government) save money due to transferred risk, use of increased expertise by the private sector and the additional time given to pay off the project (MIT, 2008).

7.2.1.2. Concessions or Franchising

In France, Public-Private Partnerships (P3s) are not a new concept, but are said to date back to the 1600s when railway, water and lighting, among other services, were first developed under P3 programs; the technique is used widely and is considered to be quite effective. Although the concept is not new, it is still widely used and deemed effective. The concession or franchising system is one of the most common forms of P3 financing for the construction and management/operation of municipal infrastructure in France. In 1995, 75% of the population was serviced with water under such a P3 contract. A long-term concession contract is signed between the public sector and one or more private companies, and the infrastructure is then returned to the public sector at the end of the contract. The private company is responsible for supplying a service to the consumer directly; the revenues coming from the service charges, or user fees. The contract clearly stipulates laws and regulations that must be followed in providing the service (Grimsey and Lewis, 2004). The use of a franchising contract thereby limits or controls the number of companies providing a particular service.

Franchising infrastructure has also been experimented with in the U.S. for toll roads and wireless communications (MIT, 2008). Bulgarians were responsible for an award winning concession project: the Sofia Water and Wastewater Concession Project. The city of Sofia's water supply system, which serves over 1.2 million residents was severely deteriorated and old, it was managed with outdated techniques, resulted in low revenue, generated high volumes of wasted water through leaks and, finally, was subject to very little investment. Capital investments greater than US$150 million are the result of the concession project. Figure 7.1 shows the structure of the concession program. The European Bank of Reconstruction was the primary lender to the concessionaire, which together with the shareholders were designated 75% of the shareholding and management responsibilities. The project, which began in 2000, has been successful due to a long list of factors, which include:

- Its organization since the start of the project;
- The time taken to carry out feasibility studies to evaluate the risk of a concession program;
- The detailed contract documentation prepared by the municipality and its advisers;
- The multi-stage procurement process that ensured dedicated interest by bidders;
- A competitive bid with a 15% increase in the price of water;
- Clearly defined objectives;
- A balanced contract;
- Structured negotiations; and
- A strong commitment from the municipality (Grimsey and Lewis, 2004).

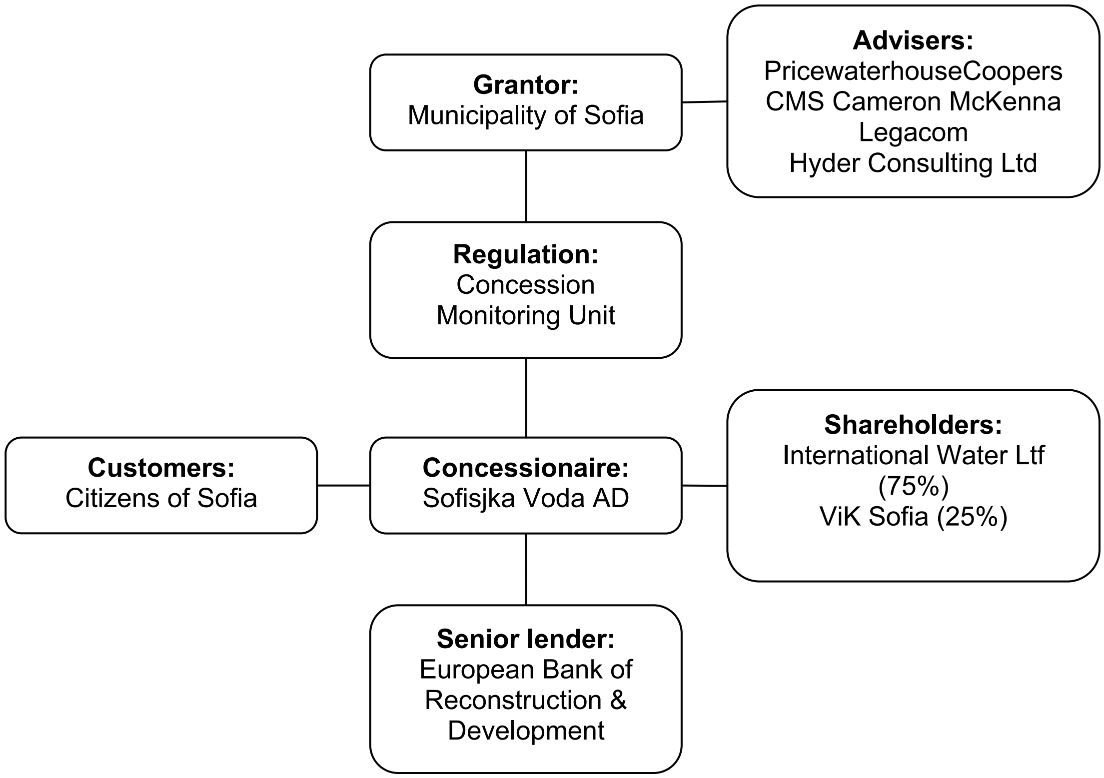

Figure 7.1 Structure of the Sofia Water and Wastewater Concession Project (Grimsey and Lewis, 2004).

7.2.2. ***Sponsorship***

It is considered difficult by some to convince a private company to sponsor the public sector for maintenance of infrastructure, in exchange for publicity. However, with increased fear and aggravation from the public, a company who initiates such a program would be recognized for its civic duty and commitment to the improved asset or service infrastructure, possibly in the company's area of expertise. For example, automobile manufacturers could sponsor a high traffic and deteriorated stretch of highway, in exchange for publicity along the highway that highlights the company's commitment to improving automobile ridership in more ways than just through the manufacturing of exceptional automobiles. GE, for example, who over time has been a leader in purification technologies can sponsor the maintenance in an area with severely affected water distribution systems. Other eco-friendly firms who have jumped on the sustainability bandwagon and are keen on promoting green practices could sponsor improvements in the area of transit, in exchange for advertisements on the subway platform and on the sides of buses, for example. The idea of sponsorship may seem idealistic and far-fetched to some: how long would such a program be successful in creating community service recognition of sponsors? Would the investment made by sponsors be really worthwhile?

The American Adopt a Highway Maintenance Corporation (AHMC) and other corporations of its kind in various states are responsible for promoting funding of this type. Sponsors such as Disneyland, Sony Corporation, Verizon and the United States Postal Service have been involved in the Sponsor-a-Highway/Adopt-a-Highway program. The program has been successful in various states; sponsors claiming that old and new customers recognize and comment on the good citizenship being exposed fom the program. The Corporation cleans and maintains a section of highway for a regular fee provided by the sponsor, whose donation is based on the location and the service mandated by the Department of Transportation in the particular state (AHMC, 2008).

Other corporations exist, which hold the same responsibilities as the AHMC in different states. In some states, companies prefer that their own team of employees go out to perform clean-up of highways on a regular basis, rather than paying a fee to an organization who will perform the work for them (hence the use of the term “adopt-a-highway” as opposed to “sponsor-a-highway”). In this case, the Department of Transportation supplies these teams with safety jackets and the other tools needed to perform the work. Again, the company is recognized for their work with a billboard along the highway that they cleaned. The term “maintenance” when discussing this program does not refer to actual extensive road repairs, but primarily to the act of removing litter from the sides of the highway. Therefore, while this particular sponsorship program does not take care of the needed road repairs and upgrading activities, it ensures that litter cleanups, which can be expensive in some states, do not take away from the funds available for these more extensive repairs needed.

Such an example of adopting a sponsorship program for the improvement of infrastructure can be extended to the various infrastructure categories, and incentives for participating sponsors can be improved as well. To promote the use of public transportation, for example, a company can offer incentives to the users. For example, a cellular telephone service provider sponsors a subway system for a particular month, then all users who have a subway pass as proof of usage may present that pass throughout the entire month at one of the retail location of the service provider and receive a discounted rate on the purchase plan. This type of incentive would attract subway users into one of the provider's stores. The latter is but one example of how marketing, besides the common billboard, can be used in combination with the sponsorship program to create a greater incentive for sponsors and help generate needed funds by promoting the sponsors image as a "dedicated citizen".

7.2.3. ***Infrastructure Banks***

One alternative to the funding mechanisms introduced thus far is the infrastructure bank, which has already made some headway in the U.S., primarily in the area of transportation and transit infrastructure. Figure 7.2 illustrates the functioning of a U.S. state infrastructure bank (SIB) that finances transit and transportation infrastructure. The bank is initially established and capitalized with federal and other government contributions. After a project application and selection process, the selected projects are funded from the capitalization reserve through low-interest loans and credit enhancements. Loan terms typically range from 10 years to 30 years (U.S. DOT FHWA, 2008). In some states, bonds are issued in addition to financing with loans. Repayments are recycled in the SIB accounts for future projects, thus making this funding alternative a "revolving loan fund".

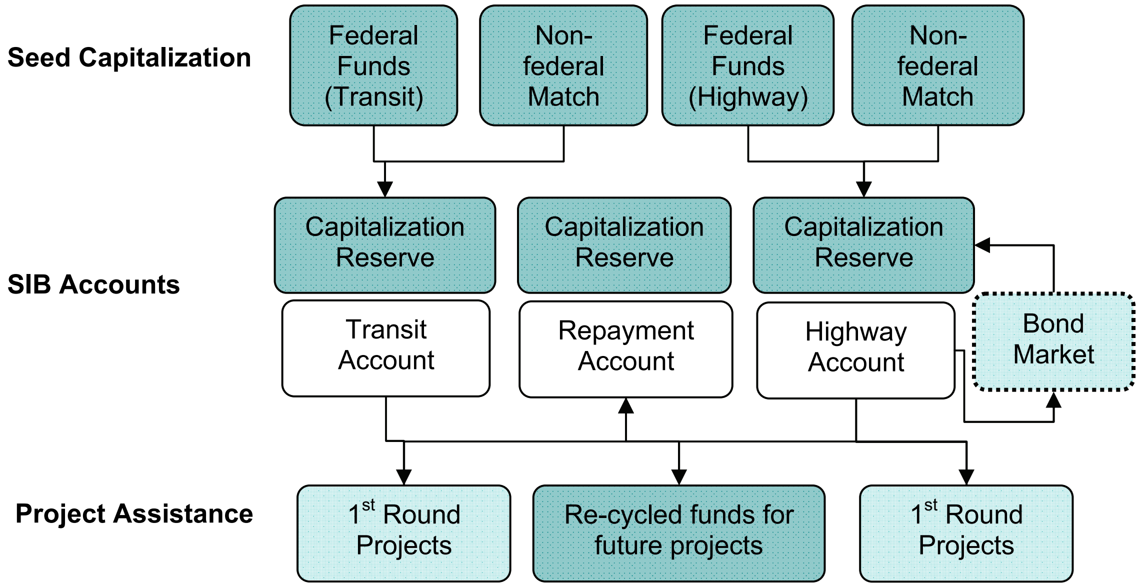

Figure 7.2 Structure of state infrastructure banks (reproduced from U.S. DOT FHWA, 1997)

In 1996, 10 states adopted SIBs under the SIB Pilot Program established under the 1995 National Highway System Designation Act: Arizona, California, Florida, Missouri, Ohio, Oklahoma, Oregon, South Carolina, Texas and Virginia. Initial capitalization by the Federal government was $150 million, which was allocated in varying amounts to each participating state. In only five years since the start of the pilot program, loans were issued and helped meet project objectives for 245 projects. The obvious success of the pilot project has extended this financing alternative to a total of 32 states (U.S. DOT FHWA, 2008), but the structure and governance of each state's infrastructure bank may vary. For example, accounts may be housed in the state's department of transportation or in another transportation agency, so long as the required financial expertise is available (U.S. DOT FHWA, 1997). Furthermore, the SIB in some states extends further than for the sole financing of highways and transit systems. For example, Figure 7.3 illustrates the main structure of the Pennsylvania Infrastructure Bank

(PIB), which helps fund highway/bridge, transit, aviation and rail freight infrastructure.

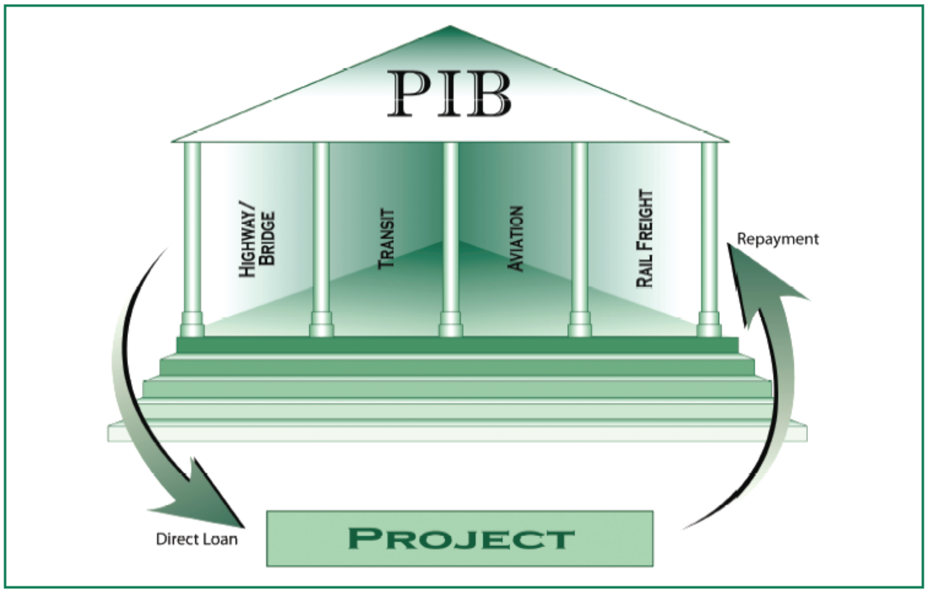

Figure 7.3 Main structure of the Pennsylvania Infrastructure Bank (U.S. DOT FHWA, 1997).

In August 2007, Senators Dodd, Chairman of the Senate Committee on Banking, Housing and Urban Affairs, and Hagel introduced legislation to create a National Infrastructure Bank in the U.S. to help finance major infrastructure projects of regional and national importance that are not adequately financed by other programs or means, in the various infrastructure categories (i.e. water supply, transportation, transit, etc.). The legislation – the *National Infrastructure Bank Act of 2007* - was coincidently introduced the same day as the Minnesota Bridge collapse. The bank acts independently of U.S. government and is led by a board of directors, comprising five members; a group of civil service staff; and one member is appointed inspector general, responsible for overseeing the daily operations of the bank (WaterWeek Staff, 2007).

7.2.3.1. A Canadian Infrastructure Bank

Development of an infrastructure bank poses many benefits:

- Provides a low-cost funding alternative when funds are unavailable through other sources;
- Enables more rapid project planning and project completion, particularly for emergency repairs, maintenance, rehabilitation and replacement projects;
- Funds are recycled for future projects;
- There is increased investment by all orders of government;
- Helps restructure the role of the federal government in infrastructure financing (Dodd and Hagel, 2007);
- There is a tendency for more private investment due to funding security and increased federal investment (U.S. DOT FHWA, 1997);
- In the long-run, minimizes the funding needed by all orders of government;
- If managed properly and the application/approval process taken seriously, there is stricter control of funding allocations;
- Leads to little political interference in funding allocation and project selections;

Finally, as discussed earlier, one of the major disadvantages to present government programs are their duration and short-term vision. An infrastructure bank would, therefore, ensure a sustained funding source by complementing traditional funding programs, which typically only last for a government parties' tenure.

Therefore, it is not only in the best interest of federal, provincial and territorial governments to provide equal initial capital investment to establish an infrastructure bank in Canada, but with the incentive of increasing the nation's international competitiveness, private companies and organizations should be persuaded to invest their money as well. A Canadian infrastructure bank can help the public and private sectors finance upgrading (maintenance, repair, rehabilitation and replacement) and new infrastructure projects. These projects need not be limited to transportation needs, but to all infrastructure types.

7.3 Assessing Financing Methods

There are many financing techniques available for consideration. It is, therefore, important to be able to assess which technique is most appropriate for a given project, activity or planned long-term investment. Many sources have presented the main criteria used to assess and evaluate the different financing mechanisms. The seven main criteria are introduced in Table 7.4.

Table 7.4 Main criteria for evaluating financing alternatives (sources vary).

Criteria	**Details**
Efficiency	▪ A measure of the impact the funding mechanism poses on society: is the situation improved for people or not? ▪ A funding mechanism is efficient when it does not alter the "economic decisions" made by individuals. For example, people will not move away, change job or withdraw from using a particular service due to a new imposed tax, toll or other enforced form of payment. ▪ In some cases, a change of lifestyle and "economic decision-making" is advantageous. For example, where fees are imposed to reduce water consumption, garbage per home, etc. (Slack, 1996)
Equity	▪ Refers to the fairness of charges on individuals of different classes (i.e. the less wealthy should not be deprived of certain services). Individuals should pay according to their income bracket. ▪ Refers to the fairness of charges on individuals of different generations. For example, charging for the use of an asset over its service life is fair, as opposed to charging one generation and then removing fees for the service for later generations. ▪ Refers to the fairness of charging people according to the benefits they receive (i.e. one should not pay significant amounts for a service he will never benefit from) (CMHC, 1992)
Effectiveness	▪ A measure of the revenues collected and their ability to cover the service costs. (CMHC, 1992)

Table 7.4 (Continued)	
Environmental Sensitivity	▪ A financing mechanism that considers the costs to the environment imposed by the service (e.g. watermeters are used to collect funds for maintenance of water supply systems, but simultaneously reduce consumption of a natural resource). (CMHC, 1992)
Innovation	▪ Measured in relation to past uses and experiences locally and on an international scale ▪ Is evaluated in terms of legal, institutional and technological constraints on use of the funding mechanism (CMHC, 1992)
Accountability	▪ Is whoever is providing/funding the service being held accountable for those who are paying for the service? (Slack, 1996)
Administrative Costs	▪ It should not be too costly to administer the financing technique in question (Slack, 1996)

CHAPTER 8

SUSTAINABLE DEVELOPMENT

8.1 Introduction

The most common and generally used definition of "sustainable development" by the United Nations is: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". There are some other definition from the various groups that bring in specific reference to the environment (including energy, pollution, climate change, etc.), ecosystems, natural resources, financial resources, the elimination of poverty and deprivation, social equity, etc., but all definitions state the common objective of maintaining and improving the quality of life of future generations. The various definitions of infrastructure include terms as "basic services", "facilities", "components of a network" or "the foundation", all for the development of a community. With an escalating deficit, increasing levels of degradation and lack of inventories in the different communities, it is obvious that the development provided by infrastructure in Canadian cities and elsewhere has not always been sustainable.

8.2 Sustainability: Considerations in Infrastructure Planning

Canada's infrastructure crisis, and related issues were reviewed in the previous chapters along with the recommendations for mitigation. In all cases, the proposed recommendations are aimed at steering practices away from an unsustainable way of thinking, planning and implementation for all aspects of infrastructure.

- <u>Short-term infrastructure programs that provide funding for a limited timeframe</u>. A proposed infrastructure bank has provided many American cities with a sustained funding source, thereby making short-term government programs complementary to this source of available and recyclable funds. Creating availability of funds on a long-term basis will facilitate overcoming the high infrastructure deficit, instead of leaving future generations with a much greater deficit to overcome, at a time when funds will be needed to meet expected future upgrading and new infrastructure needs.

- Years of neglect in maintaining a detailed inventory of all assets: their properties, construction and maintenance/rehabilitation/repair practices. With the proposed GIS –based inventory accompanying an infrastructure asset management system, future maintenance/rehabilitation/repair and replacement practices will be much simpler. Future generations will have the information needed to make informed decisions about which upgrading activities need to be performed and having a complete detailed list of all assets will permit effective project prioritization. The latter will lead to more sustainable funding allocations.
- Design, Build and Forget. Life-cycle costing and analysis ensures that the current philosophy *design, build and forget*, thereby guaranteeing that routine maintenance is considered in initial project studies and costs. Planning for routine future upkeep will diminish the chances of unexpected project costs and will make certain that future generations have the funds needed to meet maintenance needs, rather than taking funds from capital budgets planned for meeting new needs, or neglecting maintenance all together, which has led to the current situation.
- Design-focused civil engineering curricula. Changes are needed in the curricula to include renewal and maintenance strategies, which will prepare future engineers with the tools and training to place importance on upgrading existing infrastructure, as opposed to the higher focus on new construction.

It is clear that there is much more to the above examples that need to be considered in infrastructure planning to ensure sustainable development in different infrastructure categories. The following sections comprise initiatives and considerations that are making headway increasingly to “green” infrastructure planning and construction. Each of the infrastructure categories are applicable to the considerations suggested. In other words, the following considerations should be made in the design, construction, maintenance, management and operations of all infrastructure types:

- Life cycle costing and analysis;
- Waste reduction;
- Quality control;
- Environmental considerations; and
- A shift to "greener" design and construction

Each consideration will be presented by sampling only of the main infrastructure categories, thereby presenting one example of how such a consideration can be made a common practice to increase sustainable development in the field. The following can, therefore, be considered a sample presentation of best practices highlighting how different municipalities in Canada and around the world are acting to implement the various sustainable development considerations. The initiatives presented are also aimed at demonstrating how considerations for sustainability in infrastructure projects do not only arise in changes in planning, design and in construction practices, but they may also come in the form of marketing, education, and community involvement strategies.

8.3 Life-Cycle Cost Analysis

The Federal Highway Administration (FHWA) defines value engineering (VE) as "the systematic application of recognized techniques by a multi-disciplinary team which identifies the function of a product or service, establishes a worth for that function, generates alternatives through the use of creative thinking; and provides the needed functions, reliably, at the lowest overall cost" (Tufty, 1996). Therefore, a critical part of value engineering is life-cycle analysis (LCA) and life-cycle costing (LCC), which are performed in the development phase of VE to immediately aid in selecting the optimal (or cost-effective) project alternative (Tufty, 1996). LCA thus includes LCC, but it is more general in describing the analysis of the various alternatives in terms of quality, performance, environmental impact and cost throughout the asset's useful service life. Together, these are also often referred as life-cycle costing analysis (LCCA). Without these steps in infrastructure planning, it is not possible to accurately compare the costs of design alternatives, for implementation of the project in the present dollar values.

As the name implies, LCC involves considering the costs of all activities throughout the useful service life of the asset, from the initial planning stages to its final decommissioning after its useful life. Therefore, by bringing LCC into project planning, the owner and project engineers are immediately aware of not only the initial costs of procurement, construction, etc., but also the costs of inspecting, maintaining, rehabilitating/repairing, operating and decommissioning or replacing the asset. LCC involves accounting for depreciation, varying interest rates and equivalent costs for different time periods. Therefore, LCC diminishes the risks of cost overruns and ensures that future generations have the awareness and the resources necessary for future upkeep and management of an asset.

An important aspect of LCA involves both analyzing the asset as an entity and analyzing its components separately. Considering a new highway project for example, it is clear that the life-cycles of the various components of the highway will be quite different. The asphalt bridge deck would typically have a shorter life-span than say the abutments, due to wear and tear, and on the environment and exposure to any aggressive agents. Risk engineering is an essential companion of LCA, requiring that each component be considered separately to accurately determine the risks of deterioration, physical damage, etc. In turn, one can determine the maintenance and upgrading needs for each component, which may be quite different, requiring that maintenance and upkeep are appropriately suited to the life cycle of the component. The example of transportation infrastructure will continue to be used to give examples of applications of LCCA.

8.3.1. ***Transportation Infrastructure***

8.3.1.1. Heavy Lift Rapid Replacement Technology

The Queensway Bridge in Ottawa, Ontario was the first bridge in Canada to be built overnight. The technique used to replace the bridge is known as "heavy lift rapid replacement technology" and has already been adopted in the U.S. and in Europe. Replaced in the summer of 2007, the old Queensway bridge deck was removed with a flatbed hydraulic lift and a new deck constructed off-site was brought on-site and inserted over the existing abutments (Piunno, 2007). Some people have stated that the technique is analogous to building legos. Costing close to $9 million, the bridge saved the government $2.5 million and obviously eliminated two years of construction, which would have been needed to replace the bridge using conventional methods (Lurie, 2007). The use of heavy lift rapid replacement technology is an example of a technique that promotes long-term planning and, thus sustainability:

- Considerably cutting on-site construction time eliminates many of the socio-economic impacts related to transportation projects, such as the inconveniences and costs of high congestion on highways;
- Lowering congestion levels further helps to reduce greenhouse gas emissions and productivity losses; and
- Impacts on nearby ecosystems are considerably reduced.

The few benefits listed here bring up other costs that need to be considered for an accurate LCCA. These are the socio-economic impacts and user costs that result from construction, maintenance/repair/rehabilitation and replacement activities that will be implemented throughout the bridge life cycle, which are often neglected because it is sometimes difficult and cumbersome to identify and evaluate them.

This technique is not suited for all bridge types, particularly the many bridges that need complete replacement due to their age and high levels of degradation. However, this type of technique should be considered in suitable situations, e.g., for short-spans on steel girders. Additionally, new bridges should be constructed with the intention of being able to implement this technology during their life-cycle. This method of construction would therefore address the fact that the bridge deck will need to be replaced long before the end of the useful service life of the other bridge components. In turn, this would permit future generations to more easily replace the deck without affecting the other structural components, or without demolishing and replacing the entire structure, which would cost considerably more.

8.3.1.2. Life-Cycle Management Model

The New York City (NYC) Department of Transportation in collaboration with Columbia University has implemented a life-cycle cost-benefit assessment for varying bridge maintenance strategies. The New York State DOT's inspection system involves rating each bridge component on a scale of 1 to 7 (where 7 means the component is new and 1 means that the component is close to failure) and these ratings are then considered in assessing 13 bridge components in terms of the impacts of their condition on the overall quality and performance of the entire bridge. Past experience, and 20 years of annual/biannual bridge condition ratings and inspection records of NYC bridges were used to help quantify the effect of varying maintenance strategies on structural performance of the bridges (Yanev et al, 2003). Table 8.1, for example, shows an assessment of the costs of repairing 13 bridge components (upper left corner of the table), the costs and effectiveness of 15 different maintenance tasks if fully recommended maintenance levels were considered (upper right of the table) and the bridge data input that must be entered (bottom left) to obtain results of the costs that these repair/replacement and maintenance levels would impose on NYC and the user (bottom right).

Table 8.1 Example of a LCCA adopted in NYC for a bridge undergoing recommended maintenance levels (Yanev et al, 2003).

Components & Repair Costs			Tasks, Cost At Full Maintenance and Effectiveness			
Bearings	100,000	$ each		Cmli		Kmi/Cmli
Backwalls	100,000	$ each		$/ft^2	$/m^2	
Abutments	100,000	$ each	Debris removal	0.15	1.63	0.775
Wingwalls	100,000	$ each	Sweeping	0.04	0.43	1.186
Bridge seats	100,000	$ each	Clean drainage	0.06	0.61	1.995
	$/ft^2	$/m^2	Clean abutments and piers	0.18	1.95	0.568
Primary members	100	1,080	Clean open grating deck	0.00	0.04	0.00
Second members	100	1,080	Clean expansion joints	0.21	2.29	0.505
Curbs	10	30	Wash deck and splash zone	0.09	1.02	0.567
Sidewalks	10	110	Paint	2.35	25.27	0.025
Deck	80	860	Spot paint	1.55	16.65	0.035
Wearing surface	12	130	Sidewalk & curb replacement	0.09	0.93	0.116
Piers	100,000	$ each	Pavement & crack seal	0.15	1.64	0.818
Joints	25,000	$ each	Electrical device maintenance	0.07	0.78	0.000
			Mechanical component maintenance	0.07	0.71	1.222
Input Bridge Data			Wearing surface replacement	0.09	0.97	0.340
	ft^2	m^2	Wash underside	0.86	9.25	0.117
Bridge Area	30,000	2,790	RESULTS			
Number of spans	10		Maintenance level		100.0	%
Material (steel/conc)	s		% of full maintenance cost		100.0	%
Open gratings (y/n)	n		Deterioration rate used		E	
Deck (mono/overlay)	o		Expected life		150	years
Deck joints (y/n)	y				$/ft^2/yr	$/m^2/yr
	$/ft^2	$/m^2	Maintenance costs		5.96	64.15
User cost –repair based	30	323	Repair costs		5.35	57.58
–rating based	25	269	Replacement costs		12.00	129.17
NYC cost –repair based	25	269	NYC costs		7.24	77.95
–rating based	20	215	User costs		8.77	94.39
Replacement cost	1,800	19,380	TOTAL ANNUAL COSTS		39.32	423.23

8.4 Waste Reduction

Between 25% and 33% of the waste generated in Canada comes from the construction industry, including the waste generated by renovation and demolition practices (Catalli, 1999). The waste hierarchy *re-use, reduce, recycle* – and the often forgotten fourth "R" that is *rethink* may seem like common sense to many, but is only drawing the deserved attention now with the present environmental concerns. The following are what some companies and municipalities are doing to encourage the three "Rs", and thus reducing the amount of waste directed to landfills. Waste reduction does not only have to comprise solid wastes, but can consist of minimizing wasted resources, such as potable water. In Montreal alone, it is estimated that close to 50% of treated water is lost through leaking pipes, highlighting the demand for rehabilitation and quality control in avoiding loose joints during construction. In Canada, this number appears to be less, but nevertheless worrisome at approximately 30% (Environment Canada, May 15 2008). Minimizing water consumption can at least help counteract the resources wasted from treated water that is lost through leaking pipes. Waste reduction in infrastructure considerations need not be limited to the areas of water supply and materials, which have been selected for demonstration in the following sections, but energy conservation, municipal solid waste programs and landfill management can also be added to the list.

*8.4.1. **Waste Management***

8.4.1.1. Materials Recycling

Use of waste materials and recycling in the materials industry is quite broad, ranging from the use of supplementary cementing materials in cement production to using certain wastes in asphalt pavement binders. The example given here pertains to recycling of materials on-site during demolition activities using portable crushers, however, few contractors have invested in portable crushers for demolition practices. These portable units can crush concrete and asphalt, which can be reused as backfill, and wood, glass, ceramics and plastics among other materials that often require long and frequent transportation off-site to dumps during the demolition process. Asphalt can also be reused in new pavements. While reluctance to change is again the culprit to common use of these devices, more contractors are noticing that companies who have adopted this environmentally-friendly alternative to debris and fill transportation are being granted projects due to lower bidding. Furthermore, on-site crushing does not require additional labor, as only one worker is needed to operate and supervise the crusher. This practice is thus economical, environmentally sound, and easy to implement. Greenspoon Brothers Ltd. of Brampton, ON has used a portable crusher for years now. In 1989, they crushed approximately 50,000 tons of concrete in the demolition of the Good Year Tire Plant in Toronto, ON. They feel that their investment in this technology has been extremely profitable since then (Johnson, 1999).

8.4.1.2. Water Conservation

The United Nations (UN) recommends that a minimum of 50L of water is sufficient for one person's daily needs, including drinking, sanitation, cooking and washing. More than one billion people around the world did not even have that minimum provision in 1990 (Kirby, 2004). Figure 8.1 shows the average consumption (litres/day) for different continents, with reference to the UN's minimum requirement. Canadians are up to par with the American average, which is 12 times greater than what is deemed sufficient by the UN. While many Canadians believe that Canada has 20% of the world's freshwater sources, only about 7% of this supply is "renewable". The rest is retained in glaciers, underground aquifers and lakes, and more than half flows northward, away from the bulk of the population (85%) that resides in the south of Canada (Environment Canada, May 15 2008).

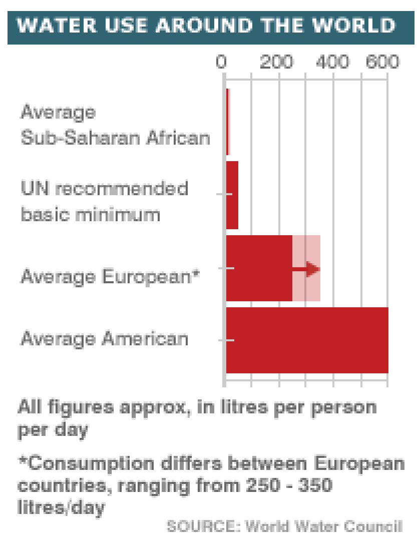

Figure 8.1 Average water consumption (litres/day) in different continents (Kirby, 2004).

Municipal water conservation strategies and supporting innovations include the following:

- Water metering: In 1999, 56% of Canada's urban population had watermeters. A study during this time showed that citizens metered with a flat rate consumed 70% more water than those metered using volume-based costs. Including a consumption-based fee for sewage treatment also further reduced residential and industrial consumption (Environment Canada, May 15 2008).
- Water-saving home appliances: Considering water savings in new construction and renovations can significantly aid the consumer in conserving water. Low pressure showerheads and toilets that reduce the amount of water consumed per flush are some examples. Greywater systems are also emerging in some new green buildings in Canada. These systems enable the reuse of water from baths, showers, washroom sinks and laundry for toilet flushing.
- Leak detection and repair programs: Municipalities who are aware of large losses of treated water through leaking pipes are encouraged to adopt a leak detection and repair program. Environment Canada studies have shown that up to $3 can be saved for every $1 spent in a leak detection program (Environment Canada, May 15 2008).
- Public education: Informing the public of conservation strategies and their benefits, and the consequences if the strategies are not implemented, is again a needed task, particularly in districts where conservation strategies are implemented. Educating the public would tend to increase approval of such strategies and policies.

Environment Canada has grouped these strategies and others into four fundamental categories. These are structural (metering, greywater systems, treatment plant improvements, efficient sprinkling/irrigation technology), operational (leak detection and repair programs, elimination of combined sewers, restrictions on water use), economic (innovative/efficient pricing, incentives through tax credits), and socio-political (codes, standard, regulations, education and knowledge-sharing) (Environment Canada, May 15 2008).

8.5 Quality Control

The inquiry into the De La Concorde Bridge Collapse in Laval, QC determined that there was lack of quality control, or more precisely, insufficient and poorly placed steel reinforcement at critical locations. The inquiry into the tragedy in Walkerton, ON in 2000 also showed that lack of quality control was a major cause of the E. Coli contamination of the town's water supply. These are only two examples of the consequences of taking quality assurance lightly, yet the consequences of each have emphasized the need for stricter standards and improved quality control.

8.5.1. ***Water Treatment***

The town of Walkerton has implemented many new initiatives in response to the recommendations listed in the results of the inquiry. A new inspection program was implemented in 2002 to comply with new legal requirements that a system with a detected deficiency should be inspected at least once a year; this would ensure quality control. In addition to these inspections, other planned and unannounced inspections are carried out by the Ministry of the Environment (MOE), which has also implemented an information data system to stay abreast of the water reports and test results, besides helping to monitor the quality of source water. Since 2002, MOE requires continuous chlorine and turbidity monitoring of all groundwater sources that may be affected by surface waters, or that supply water to a large population. The latter would have helped to avoid the contamination of a well that did not have the required chlorine disinfection, and which was contaminated by surface runoff. Another cause of the tragedy was negligence by the water managers who were not knowledgeable of the consequences of water test results and did not see the seriousness of acting on identification of a contaminant. As a result, water system operators must now be recertified periodically. Certification must follow an examination which not only emphasizes technical subject matter, but also health risks, regulations and the procedures to follow when a risk to public health is identified. A more extensive training is included in this procedure as well (Ontario MOE, 2007).

Other Canadian cities have improved and created more stringent water quality control regulations, treatment methods and stricter training of personnel as a result of the Walkerton case. It must be emphasized that it should not take another tragedy to get others to change their quality assurance methods. If a municipality is to provide safe, good quality water to its residents with treatment methods that have little environmental consequences, then procedures and standards should be updated periodically and treatment monitored continuously for a safe water supply.

8.6 Environmental Considerations

The example of transit systems will be used to demonstrate how some municipalities, transit agencies and departments of transportation are acting to relieve congestion, thereby decreasing pollution and greenhouse gas emissions. The latter will also be addressed separately to deal with the impact of climate change on infrastructure.

8.6.1. ***Transit***

Canada is the only G8 country with no federal policy for long-term transit investment. In 2007, the Big City Mayors' Caucus proposed a National Infrastructure Strategy to increase investment in public transit systems ($2 billion a year) among other needs, such as research and innovation for more efficient transit systems. There is also a strong need to increase transit ridership and decrease vehicular traffic, particularly with single passengers, to relieve congestion and reduce greenhouse gas emissions. The Canadian Urban Transit Association (CUTA) and the Federation of Canadian Municipalities (FCM) have stressed the need for incentives for the public to increase the use of transit for travel pusposes in preference to the car. In Canada, transit user fees pays for 60% of the operating costs and the remaining costs come from local property taxes.

The user costs are higher than in any other Western country, and they continue to increase every year due to the consistently increasing upgrading needs (CUTA, 2007). This is the exact opposite of the incentive needed at a time when environmental issues and congestion are of concern.

Since 2006, Canadians began benefiting from a federal tax credit on transit passes, but this incentive is not enough. Canadian cities lag behind many American cities who have developed various strategies to increase transit ridership. CUTA and the FCM are urging politicians to look at innovative and sustainable strategies, and policies and regulations that support the use of transit. In particular, these groups have recommended the use of employer tax-exempt transit passes (CUTA, 2007). This strategy has proved successful in some American cities.

8.6.1.1. Marketing: The Direct Mail Campaign

In southeastern Wisconsin, a marketing approach was adopted by the Wisconsin Department of Transportation through four public transit service providers in 1998, to increase public transit ridership in areas with low-or-declining ridership. Citizens in these areas were sent promotional mail, providing information about transit services in the community and advertisement for a promotional offer of 10 free trial rides - an offer promoted by famous local football stars, as the campaign's spokespersons. Newspaper and radio advertisement complemented the campaign. A total of 58,156 citizens were sent the promotional mail and 5,191 returned reply cards to redeem their 10 transit tickets, which were each identified by a serial number to track the new users. Of the coupons mailed, 53% were used, providing over 27,000 free rides. A subsequent telephone survey of those who had redeemed the tickets, showed that "non-riders" (or previously infrequent riders) who redeemed the tickets used an average of four tickets each; 14% of the non-riders used all 10 tickets, significantly increasing the ridership. The results showed that riding frequency also increased after the promotional campaign had ceased. The non-riders increased by an average of 2 rides per month, as opposed to the "couple of times a year" that they used the transit system prior to the campaign (Bush, 2000).

It is clear that such a promotion would be more effective and beneficial for some communities than others, as the costs of conducting the campaign may outweigh the long-term revenues obtained from increased ridership, particularly in larger municipalities. In particular, such a campaign cannot be introduced in a municipality where the current services do not meet the standards envisaged by the residents. One of the criteria for selecting target areas in the community described above was to ensure that the levels of transit service in these areas were at, or above the acceptable levels. Municipalities would certainly benefit if the transit system has outstanding services to offer, and in particular, the large municipalities can benefit from such a campaign upon introduction of a new service, or updated or modernized facilities (e.g., a new subway station).

8.6.1.2. Employer-Based Transit Pass Programs

In Denver, Colorado, Salt Lake City, and Santa Clara, California all employees of a company who wish to participate in the program receive a free transit pass, which is paid partly by the employer. It is more beneficial to the employer and more effective at increasing the transit use, to distribute the universal transit passes to all downtown employees. This program was implemented in Boulder, Colorado, and was also made available to students and staff at over 30 colleges and universities (White et al, 2002).

The *Go! Pass* was first introduced in November 1999, in Ann Arbor, Michigan, to encourage the use of public transportation by employees working in the downtown area. The City of Ann Arbor, the Ann Arbor Transportation Authority (AATA), the Downtown Development Authority (DDA) and the chamber of commerce undertook this joint venture because of the high congestion, with many employees traveling to work alone by car. The AATA applied for Congestion Mitigation/Air Quality funding (CMAQ) to help pay for program admiistration and to pay for a portion of the $25 passes (the remaining $5 portion was to be paid by the employer). For the first two years of the program, it was decided that the employer's portion of the costs would be paid by the DDA and the city. Subsequently, the employer participation in the program was high, as was the increase in transit ridership. After two years, the employers were expected to pay $5 per employee for transit passes, thereby decreasing the number of participating employers, but nevertheless increasing the number of riders who got used to commuting to work (White et al, 2002). A 2006 study showed that the number of daily cars entering the downtown area decreased by approximately 112 cars per day, and between 2001 and 2005, there was a six percent increase in the number of employees regularly taking the bus to work. People who benefit from the *Go! Pass* claim it to be a huge perk in their job and the main reason for those who do not use the *Go! Pass* is that free parking is provided by their employers (Levine et al, 2005).

8.7 Greening Construction

Green construction practices are making headway in a variety of forms. Trenchless technologies, for example, have provided municipalities with an alternative approach to open cut operations in maintaining and rehabilitating underground infrastructure. There is hesitation to experiment with this new technology because of perceived high initial costs and a need to educate and train existing personnel to use these new methods. However, trenchless technologies have reduced the environmental and social costs that traditional methods of full excavation pose on communities who complain for months of dust, inconvenience, damage/killing of greenery along property lines, noise and pollution caused by the use of more trucks and machinery on site, pollution caused by transporting backfill and excavated earth/waste, etc.

In the case of transportation infrastructure, some communities are using recycled materials from the old pavement as materials for the new asphalt pavement. Grey County eliminated a scrap tire problem by using crushed tires in their asphalt mixtures (Details later in Chapter 11). Therefore, more environmentally-friendly alternatives to the traditional practices are emerging in different areas of infrastructure.

8.7.1. Buildings

Buildings "account for 37 percent of the total primary energy use in Canada, and roughly 30 percent of the total greenhouse gas emissions" (CaGBC, 2006). The Leadership in Energy and Environmental Design (LEED) certification is a green building standard providing designers and builders with guidelines for "greening" facilities, and a rating system or indicator for sustainability. The prerequisites and credits set out by the Canada Green Building Council (CaGBC) fall under the following categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation and design process. Standards in these categories include the various considerations that will provide more sustainable building components (e.g., green roofs, energy efficiency, solar power, maximized natural light, water savings, greywater systems, indoor and outdoor environmental quality, materials selection, reuse of recycled materials, etc). A project is then assigned a total point score based on the criteria satisfied and the prerequisites in each category, finally leading to one of four certification levels (i.e., certified, silver, gold or platinum) (CaGBC, 2008).

Since the founding of the CaGBC in 2002, there have been 100 LEED certified projects in Canada, 34 in British Columbia, 22 in Alberta, two in Saskatchewan, two in Manitoba, 31 in Ontario, five in Quebec, two in New Brunswick, one in Nova Scotia, and one in the Northwest Territories. These consists of five platinums, 39 golds, 32 silvers and 24 certified (CaGBC, 2008). Hundreds of other projects have registered to be certified. This indicates that some provinces have made considerable progress in the area of green building. Initial costs of following LEED standards and obtaining LEED certification is one factor that turns many municipalities and private companies away from the idea, especially since this involves many companies from changing the construction practices they have used regularly in the past. However, the life-cycle costs of such facilities show that initial investment is worth it, due to many resulting benefits. For example:

- Considerable energy savings;
- Increased indoor air quality;
- Increased productivity in the building as the environment is new, airy and bright
- Reduced sick leaves due to improved indoor air quality and working conditions;
- Lower costs due to recycled water in greywater systems, energy savings, etc.

The City of Austin, Texas also uses a LEED standard for existing buildings (LEED – EB) to evaluate the performance of buildings under its jurisdiction. This provides an effective method of evaluating the city's operations and maintenance program (Stansberry, 2008). In Canada, LEED-EB is expected to be launched in 2009 (CaGBC, 2008). This will provide municipalities with guidelines for more sustainable maintenance and operation of community, social and recreational facilities, or other buildings under their jurisdiction. However, an education program should be enforced by provincial governments, to educate municipalities about the LEED standards, thereby reducing the initial costs and hesitations in adopting a useful sustainable practice.

CHAPTER 9

CLIMATE CHANGE

9.1 Introduction

"Climate change is the shift in the average weather occurring in a given region, normally based on the average weather pattern for a specific region. Global climate change implies change in the climate of the earth and it occurs naturally, gradually and very slowly" (Gaudreau et al, 2005). Climate change is raising concern around the globe. "Sometimes referred to as global warming, climate change is the process by which human emissions of greenhouse gases (GHG) are believed to be causing changes in the Earth's climate system" (IDeA, 2008). Changes, to the effect of temperature increases and abnormal precipitation patterns, are already being experienced. Canada has been very active in climate change research, in the development of extreme climate change scenarios, and has been among leading countries to cooperatively establish targets to reduce GHG emissions. In 2002, the Government endorsed an agreement under the Kyoto Protocol to eliminate greenhouse gas (GHG) emissions to 6% below 1990 levels by 2012 (Barrow et al, 2004). In 2007, this target was raised; GHG emissions should decrease by 20% below 1990 levels by 2020 (Environment Canada, 2008).

The climate change impacts can be advantageous or simultaneously disadvantageous. Melting glaciers, for example, will open water channels to the North which can be beneficial in creating new channels for trade and development. However, these new open channels and the easier access into the country from the North can also be a national threat, requiring the construction of new infrastructure for security measures. Also, some species e.g., polar bears, are facing extinction because of changes to their natural habitats and their inability to survive in the changed habitat. At the same time, northern populations are being required to learn to adapt to a new way a life, which is not always simple. Warmer temperatures can mean longer seasons of tourism which can be both pleasant and profitable for tourist areas. These warmer temperatures, however, are causing changes in evaporation and precipitation patterns, leading to changes in water chemistry, sea levels and soil moisture levels, negatively impacting the agriculture and fishing industries. Shorter winters and longer summers would mean a decrease in heating demands, yet this benefit would be counteracted by an increased demand for air conditioning in the projected warmer summer months. A shorter duration of ice covered waters would mean that shipping seasons would be extended, which would again be beneficial due to profitability, international competitiveness and nation building.

It is clear and well understood that the consequences of the climate change crisis far outweigh the advantages. While climate change is a worldwide problem, the extent of its effects will be experienced differently by different countries. The same is true for Canada, where different regions will face different risks and will need to cope with the climate change effects in a variety of ways, to shift from "remediation, response and recovery to mitigation and prevention" (Briceno, 2008).The abilities of some communities to adapt to climate changes will be much more difficult than others. Similarly, different industries will encounter their own set of related issues. A brief review of the issues affecting civil engineers and infrastructure planners follows.

9.2 Engineering Considerations

For engineers and infrastructure planners, climate change means a variety of things:

- Climate extremes that are currently being considered in design are representative of past climate data and are thus no longer representative of predicted weather patterns. Climate extremes will promptly need to be modified to represent future conditions if assets are to be designed for efficiency throughout their service lives.
- As weather data is an important environmental loading factor in design, the codes and standards will similarly have to change to reflect the risk that climate changes pose and should be reviewed and updated periodically to account for

the progress in weather extremes research. Present loading factors still reflect out-of-date weather patterns (Steenhof, 2008).

- Disaster management should be considered a priority. There should be a backup plan ready if any infrastructure assets important to the functioning of a community are damaged.
- Links should be drawn between extreme weather events and an infrastructure's threshold (Auld, 2008). These forensic studies can already be performed in the North where damage to infrastructure due to climate changes is readily visible. These can provide valuable information for further preventive action.
- Existing assets will have to be evaluated in terms of the risks that climate changes pose on their structural integrity and performance levels;
- With a detailed inventory of all existing assets, it would have been easier to accurately prioritize the assets that are most at risk. From the list of at- risk assets, engineers should assess whether these can be retrofitted for preventive action against the impact of climate change (Auld, 2008).
- There is a need to develop specialized agencies to assist municipalities for the recommended condition assessments and to incorporate adaptation planning into their infrastructure management practices (Ness, 2008).

Lastly, modifications will be required in the design and construction of different infrastructure asset types. Similarly, risk assessments of existing assets are necessary to help establish optimal alternatives when planning to retrofit the existing assets or mitigate the effects of the predicted climate changes. For example, if stormwater pipes are found to be under-capacity for the predicted rise in precipitation, then not only should the size of the existing pipes be re-evaluated, but more green spaces could also prevent the rapid draining of water into catch basins. Therefore, not only should the infrastructure be retrofitted, but engineers need to work closely with urban planners to plan for alternative and economical solutions to ensuring that existing assets remain serviceable. While much work is obviously required to consider climate change in the civil engineering profession and curriculum, as well as in the construction industry, Auld (2008) from

Environment Canada has stated a positive aspect of the climate change crisis on engineers and planners. She stated that overcoming the infrastructure crisis is a challenge, however, the much needed infrastructure rehabilitation and reconstruction is creating the opportunity to plan for new infrastructure so that it is adapted to future climate change extremes (Auld, 2008).

9.3 Climate Change in Different Canadian Regions

Strategies to overcome the impact of the climate change would vary in different regions, where varying climatic changes are anticipated. Figure 9.1 shows the different climatic regions in Canada and Table 9.1 summarizes the main climatic events that have already affected certain regions and those that are expected to amplify in upcoming decades. Increasing temperatures are common to all regions, though temperatures are expected to increase the most in the Arctic regions. In most cases, milder winters with increased precipitation are not only expected, but existing data show that they are already occurring in some regions. Other impacts such as increased flood events and increased periods of drought, on the other hand, are particular to few regions (in this case coastal regions and the Prairie, Lower Great Lakes and South Laurentian regions, respectively). What are common to all regions are the needed changes and improvements in the way infrastructure is planned, designed, and constructed to prevent and mitigate the impact of these climatic changes.

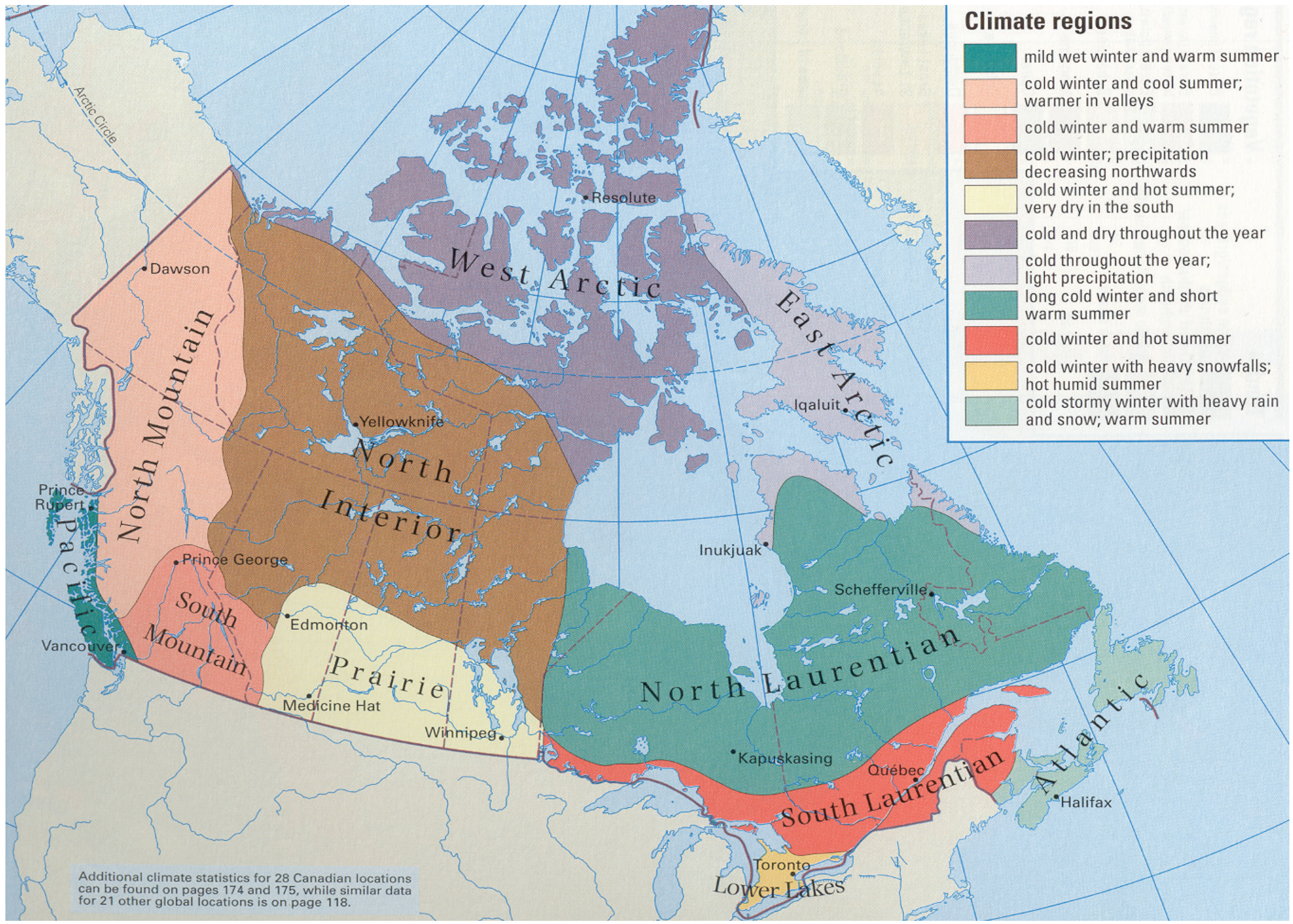

Figure 9.1 Climatic regions of Canada (Stanford, 2004).

Table 9.1 Expected climate change events in Canada's main climatic regions (information retrieved from Environment Canada, 2004).

Climate Change Event	Pacific Coast	North & South Mountain	West & East Arctic	Prairie	North Interior	North Laurentian	Lower Lakes & South Laurentian	Atlantic
Increased storm severity							✓	
Intense rainfall events							✓	
More sheet runoff							✓	
Less sheet runoff							✓	
Increased flood events	✓						✓	✓
Increased evaporation							✓	
Increased evapotranspiration				✓				
Increased periods of drought				✓			✓	
Decreased duration of lake ice cover							✓	
Lower lake water levels							✓	
Less snow							✓	
Increased winter precipitation	✓	✓	✓		✓	✓	✓	
Shorter winters					✓	✓		
Increased fall precipitation			✓		✓	✓		
Shorter winters							✓	
Rising temperatures	✓	✓	✓	✓	✓	✓	✓	✓
Melting permafrost			✓		✓	✓		
Increased sea levels	✓		✓					✓
Increased incidence of storm surges								✓
Possible differences in ocean circulation and wave patterns								✓

(Table 9.1 Continued)

Climate Change Event	Pacific Coast	North & South Mountain	West & East Arctic	Prairie	North Interior	North Laurentian	Lower Lakes & South Laurentian	Atlantic
Possible frequency of tropical storms								✓
Decreased snow cover		✓						✓
Increased aridity								✓
Possible elimination of wetlands and sloughs				✓			✓	
Decreased water levels				✓			✓	
Decrease in duration of snow cover				✓				
Decreased summer soil moisture				✓	✓		✓	
Earlier snowmelt and ice breakup					✓			
Less thick and less permanent sea ice					✓			✓
Milder winters			✓		✓	✓		
Longer summers			✓		✓	✓		
Increased snowfall						✓		
Increased rain-on-snow events		✓						
Increased risk of avalanches		✓						
Increased rate of snowmelt		✓						
Decreased summer stream flows		✓		✓				
More severe spring flooding	✓	✓				✓		
More risks of landslides	✓							
Glacier retreat and disappearance	✓							
Higher impacting river flows	✓							
Risks of forest fires	✓			✓	✓			
More insects and possible spread of disease	✓			✓				

9.4 Impact of Climate Change on Infrastructure

Consequences of the climate change events listed in Table 9.1 are numerous. Lower soil moisture levels and higher evaporation rates due to increased temperatures, for example, will lead to decreased surface runoff in the Lower Lakes and South Laurentian regions. In turn, this will decrease the water levels in the lakes, where the quality is already jeopardized by industries in the surrounding areas. The 8 million Canadians that live in the Great Lakes and St. Lawrence basin and the electric power industry, that depend on the lakes for drinking water and power generation, respectively, will thus be affected by these low water levels. It is predicted that the St. Lawrence river outflow could decrease by as much as 20% (Environment Canada, 2004).

Most of the negative impacts can be mitigated, or prevented with new, or improved infrastructure. For example, higher levels of treatment may be required to counteract the effects that lower water levels could have on water quality. Water temperatures are typically higher at lower levels, which promote growth of algae and bacteria. Also, dredging will be required in some areas to offset the decreasing water levels for shipping and other activities, leading to re-suspension of toxic chemicals (Environment Canada, 2004). Furthermore, dams may need to be retrofitted, or new infrastructure for alternate sources of power generation may need to be constructed to compensate for the low levels of hydroelectric power generation. Periods of drought may also require that infrastructure be constructed to transport water to affected regions, which can be quite expensive if water is transported over large distances. Increased water levels, on the other hand, would require the construction of dikes and other flood protection schemes in coastal regions. Other examples of how some of the consequences that the expected climate changes listed in Table 9.1 will have on infrastructure in various regions are summarized:

Predicted Change: Periods of drought

Impact on Infrastructure: Decreased water levels can lead to reduced water quality, as “lower water levels and higher temperatures could increase levels of bacterial, nutrient and metal contamination […]" (NRC, 2004), causing a need for more stringent and innovative water treatment practices. Table 9.2 shows the 2001 climatic data of different regions that have already begun to experience the effects of droughts.

Table 9.2 The 2001 drought records of four Canadian regions (NRC, 2003)

REGION	**CONDITIONS IN 2001**
BRITISH COLUMBIA	▪ Driest winter on record, with precipitation being half of historic average across the coast and southern interior ▪ Snowpacks in southern regions were at or below historic low
PRAIRIES	▪ Saskatoon was 30% drier than the previous 110-year record ▪ Many areas experienced lowest precipitation in historic record ▪ Parts of the Palliser Triangle experienced second or third consecutive drought
GREAT LAKES/ST. LAWRENCE BASIN	▪ Driest summer in 54 years ▪ Southern Ontario (Windsor-Kitchener) experienced the driest 8 weeks on record ▪ Montreal experienced driest April on record and set summer record with 35 consecutive days without measurable precipitation
ATLANTIC	▪ Third driest summer on record ▪ Large regions experienced only 25% of the normal rainfall in July and August; it was the driest on record ▪ July, with 5 mm of rain, was the driest month ever recorded in Charlottetown

Predicted Change: Increased precipitation

Impact on Infrastructure: While some regions may experience droughts, others may experience the opposite and see increased rainfall patterns. This would require new infrastructure for flood mitigation. Also, increased flooding "could increase the flushing of urban and agricultural waste into source water systems" (NRC, 2004), which would again affect the levels of adequate water treatment needed. Figure 9.2 shows the areas at risk of flooding across Canada. Furthermore, the capacity of many existing stormwater systems may not be adequate to carry large amounts of rainwater, which may cause an overflow, leading to high levels of untreated water by-passing the water treatment plant and being disposed of in freshwater sources without treatment. In the case of combined sewer overflows, sanitary wastes may be disposed in the various water sources. Many existing transportation systems may not have been adequately designed for proper drainage required for extreme precipitation patterns. Drainage problems on bridges and highways can help accelerate the corrosion process. During winters, this increased precipitation along with the de-icing salts would accelerate corrosion of the embedded reinforcing steel in the bridge deck.

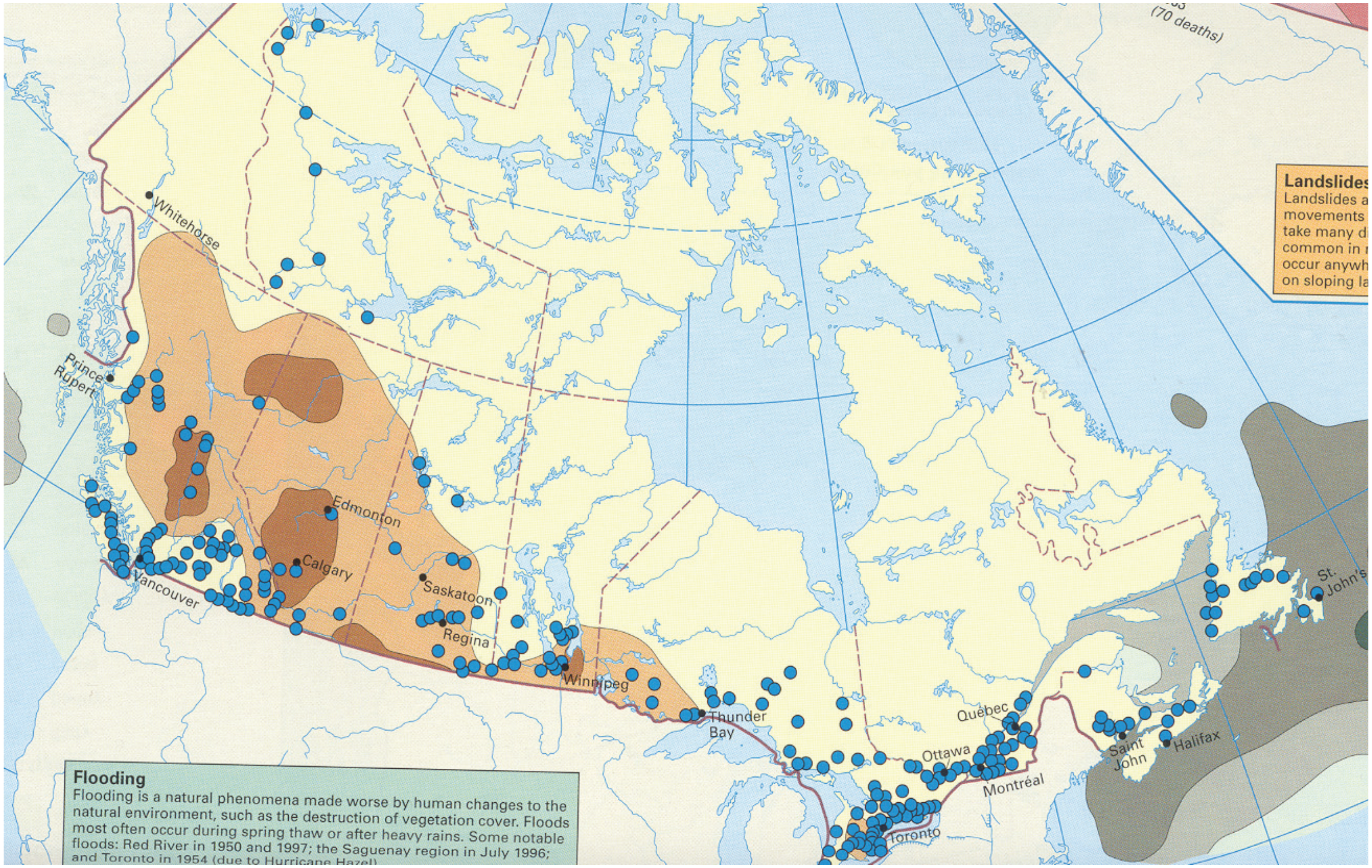

Figure 9.2 Canadian flood risk areas (Stanford, 2004).

Predicted Change: Sea level rise due to thermal expansion of ocean waters, melting glaciers, or increased precipitation (NRC, 2004)

Impact on Infrastructure: Canada has the most coastal land in comparison to any other country. Figure 9.3 shows the sensitivity of different Canadian regions to rise in sea levels. More specifically, Figures 9.4 and 9.5 show the Atlantic Provinces' and the Western Arctic's sensitivity to sea level rise. The increased sea level rise will require infrastructure for flood mitigation, to ensure protection of communities. There may be a need to abandon many offshore structures, such as offshore oil platforms, which were designed for lower sea levels. "Dykes enclosing areas lying below current high tide [levels] would have to be raised to avoid inundation by storm surges" (NRC, 2004). There will be an increase in spring runoff, placing a "greater demand on reservoirs to even out electricity supply" (Intergovernmental Panel on Climate Change, 1998). Also, this increased precipitation may exceed the retention capacity of existing tailings ponds, spilling toxic compounds into local water systems (Environment Canada, 2002). New tailing ponds must be designed accordingly, and a protective barrier should be constructed around the existing ones to prevent spilling of hazardous substances into freshwater sources.

Predicted Change: Increased runoff

Impact on Infrastructure: Due to high levels of precipitation, increased levels of runoff may be greater than the infiltration ability of the land, which leads to high levels of sediment, nutrient, pesticide and other possible waste being carried into surface waters. Existing water treatment techniques may not be adequate to treat these waters, therefore investments in additional water purification systems may be necessary. Larger green spaces should also be considered where appropriate.

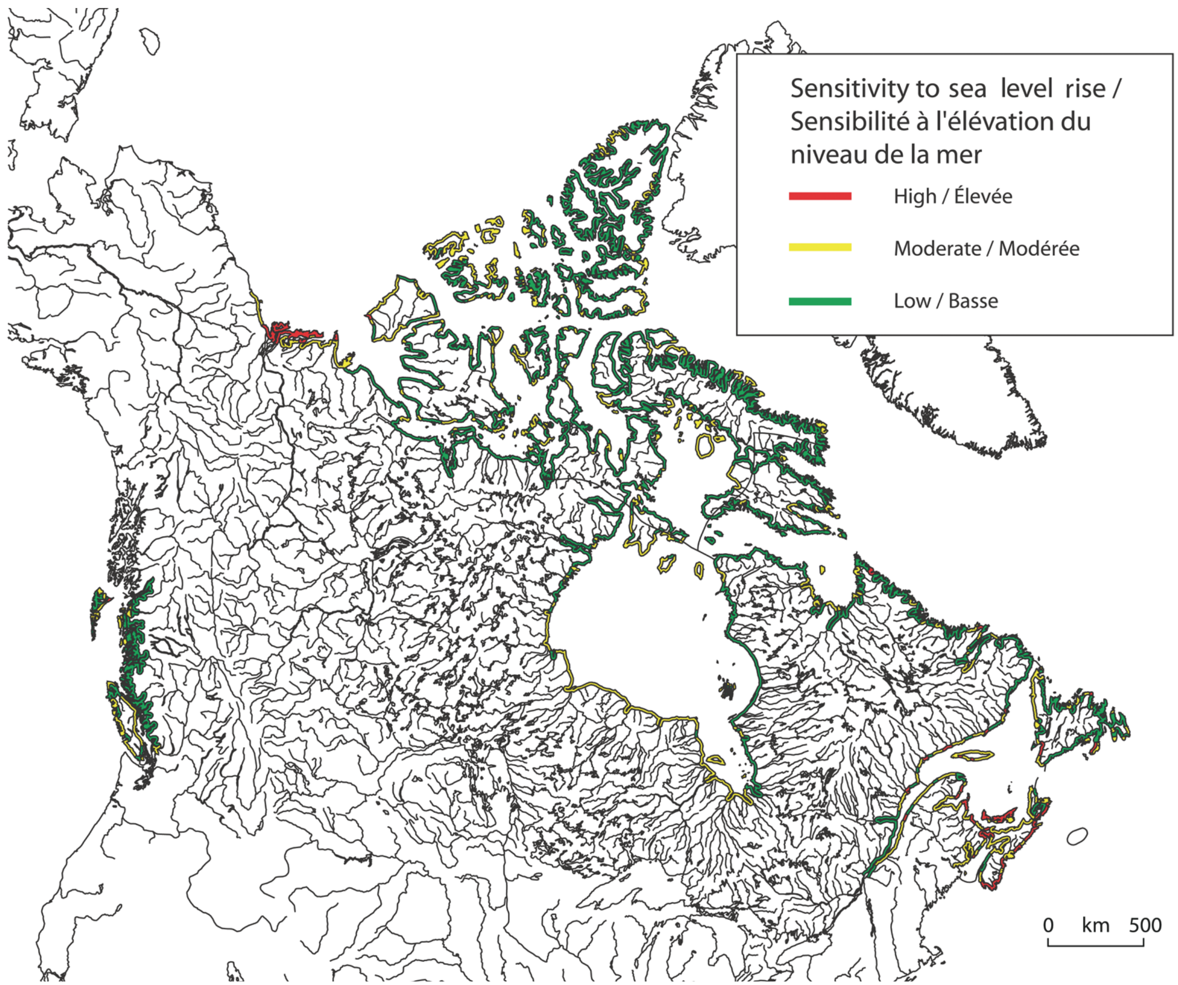

Figure 9.3 The sensitivity of Canada's coastal regions to sea level rise (NRC, 2004).

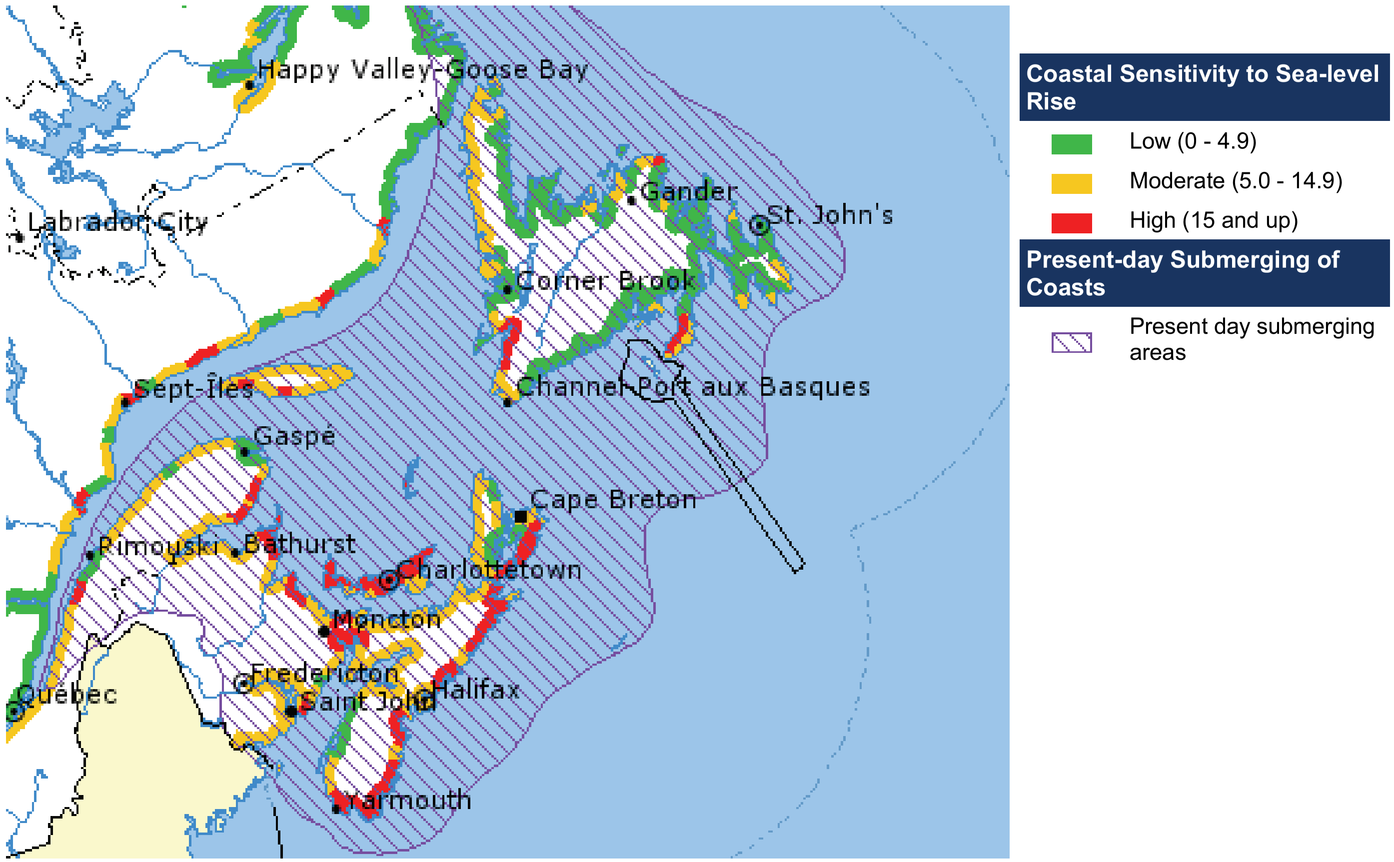

Figure 9.4 The Atlantic Provinces' sensitivity to sea level rise (NRC, 2007).

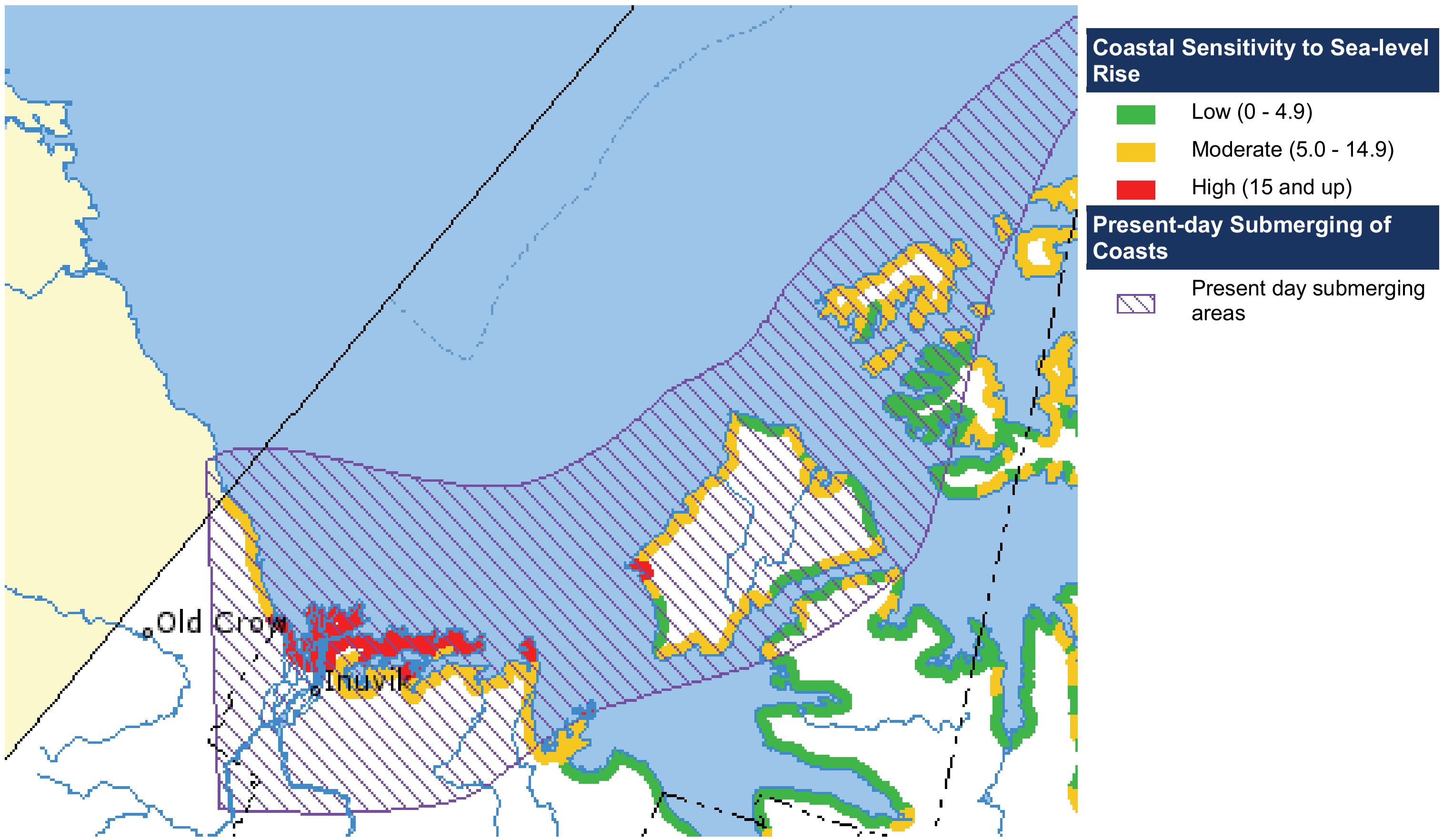

Figure 9.5 The Western Arctic's sensitivity to sea level rise (NRC, 2007).

Predicted Change: Shorter winters and increased winter precipitation

Impact on Infrastructure: This will lead to an increase in spring runoff, placing a "greater demand on reservoirs to even out electricity supply" (Intergovernmental Panel on Climate Change, 1998). Also, this increased precipitation may exceed the retention capacity of existing tailings ponds, spilling toxic compounds into local water systems (Environment Canada, 2002).

Predicted Change: Changing water flow patterns

Impact on Infrastructure: Potentially more erosion along offshore and waterfront infrastructure and increased risk of scour of pile foundations of these structures. Scour countermeasures which should be considered are: hydraulic countermeasures, structural countermeasures and monitoring. Hydraulic countermeasures are designed to modify existing flow conditions or to improve the bed's resistance to scouring caused by these flow conditions. Riprap is a term used to describe a layer or facing of rock, stone, concrete or other coarse aggregate that is placed or dumped around a structure to prevent erosion of the bed material around it. Riprap is one of the most common hydraulic scour countermeasures due to the availability of local materials previously mentioned, their low cost and the facility of placement. However, sheet-pile protection can also be used. As the name implies, structural countermeasures involve modifying a structure that has already been affected by scouring or that can potentially be affected in the future due to its environment. Pile geometry and alignment, and reinforcement of the foundation are examples. Lastly, monitoring should be achieved by visual inspection, or with the use of portable and fixed instrumentation and this should become the common practice in all inspections of structures that may be affected by scour.

Predicted Change: Increased temperatures and humidity

Impact on Infrastructure: Warmer temperatures in the summer months could lead to increased rates of deterioration of pavements and possible buckling of railway tracks. In the former case, higher temperatures will lead to increased softening of asphalt pavements, and deeper rutting under high traffic loads (NRC, 2004). Furthermore, the rate of chemical reactions increases in higher temperatures, leading to faster degradation of construction materials, thereby requiring greater maintenance and preventive measures. The physical deterioration of concrete, however, will decrease with a rise in temperature, as freezing and thawing cycles will decrease in the southern parts of Canada. In the Northern parts, the number of freezing and thawing cycles will increase, causing more deterioration due to scaling and disintegration of concrete. When considering freshwater source, higher temperatures reduce dissolved oxygen, which causes longer stratification leading to algal bloom and, hence, affecting taste and odor of the water (Krantzberg, 2007). Modifications in treatment levels may be required. Existing building HVAC systems may not be adequate to maintain comfortable temperatures and would need to be designed accordingly.

Predicted Change: Precipitation-triggered slope instability and landslides
Impact on Infrastructure: This could be a serious problem on the Pacific coast, which can damage many transportation systems in mountainous areas and other infrastructure in nearby communities. This will cause many road closures, leading to inadequate service and reduced water quality due to silt and clay entering reservoirs, thereby reducing the disinfecting capabilities of the chlorination process (NRC, 2005). There is a great need in the area of geotechnical engineering to analyze alternative slope stabilization and soil reinforcement techniques, and earth retaining structures, and hydrogeological mitigation strategies that are most suitable for areas at risk.

Predicted Change: Water levels "in ponds, lakes and dugouts are forecast to decline, in some regions, leading to changes in water chemistry, which will mean less available drinking water in some rural regions" (Environment Canada, 2003).
Impact on Infrastructure: The decreased water content can lead to increased algal bloom, which in turn can lead to lower quality level water and increasing

salinization, necessitating improved water treatment (Environment Canada, 2002). Additionally, existing water storage facilities may not be able to support long periods of drought and municipal water distribution and sewage disposal system may not be able to meet the demands of communities. This predicted change primarily affects the Prairies provinces.

Predicted Change: Ice jams
Impact on Infrastructure: The ice jams can have damaging effects on the region hydrology, and offshore and waterfront infrastructure. Dams, bridge piers, and other assets along the waterfront could possibly erode, or experience greater damage due to impact of large icings. Protection, such as fender systems should be installed on the existing and new assets that may be affected by the impact of these large icings.

Predicted Change: Increased ice-on-snow duration
Impact on Infrastructure: Will place heavier loads on buildings and other assets. A differential roof load can be detrimental to the structure and lead to high risk of roof collapse under the high load. Snow loads should be modified to account for this eventuality.

9.5 Impact of the Infrastructure Crisis on Climate Change

Deteriorated assets are helping to contribute to climate change, examples include:

- Extensive emergency road repairs, potholes and transportation systems, that do not meet the capacity needed to satisfy service demands, are all contributing to congestion. Consequently, greenhouse gas emission levels from vehicular traffic are constantly increasing.
- Transit systems of low capacity and with deteriorated assets that cause frequent service interruptions and decreased service are not encouraging the use of transit, thereby not decreasing vehicle use, particularly in congested areas such as downtown cores.
- Leaking pipes means that much treated water is being lost before it reaches faucets in homes. As a result, many treatment plant operations are being performed very inefficiently and energy is being lost in the process.
- Landfills are one of six different sources of atmospheric methane. While methane emissions are lower than carbon dioxide emissions, it is nevertheless a contributor to global warming. It is estimated that, in comparison to carbon dioxide, methane produces about one-third the amount of global warming (Enzler, 2008). High waste generation by the construction industry is not helping to reduce waste disposal here.
- Failure to recycle materials where it is often a feasible and an economical solution poses demands on the cement, steel and plastic industries. Emissions from the production of these materials are, therefore, often unnecessary.
- Social, recreational and cultural facilities that the latest *FCM-McGill Infrastructure Survey* (2007) proved to be in greatest need of repair have old and faulty building components that do not comply with the sustainability standards. Energy and water saving technologies are typically not part of these older structures.

9.6 Case Study: Arctic Canada

Emphasis is placed on the impacts of climate change in Arctic Canada, as this region will experience higher temperature increases than the southern Canadian regions. It is also the region which has begun to experience the negative effects of climate change, because most of the existing infrastructure has been built on permafrost, which has begun to melt, causing soil instability and consequential negative impacts on local infrastructure. Melting permafrost is also expected to cause landslides and release additional greenhouse gases into the atmosphere.

*9.6.1. **Climate Change and its Effect on Permafrost***

Permafrost is defined as soil, rock or sand below the surface of the earth, which remains frozen for at least two successive years. Permafrost is found beneath approximately 20 percent of the earth's land surface and, by definition, it is found in the Arctic and Antarctic regions, where the cold climate maintains the ground in its frozen state for prolonged periods of time. Records prove that some areas of permafrost have existed for periods of tens of thousands of years (Muller, 1947). The top layer of permafrost - the active layer - undergoes freeze-thaw cycles due to the yearly changes in seasonal temperatures. A thinner active layer will therefore be found in colder regions, or at higher latitudes, where the winters will have a longer and more considerable freezing effect than the summer thawing. In this case, new frozen ground resists the summer thawing due to a longer freezing period and larger frost depth. In turn, the permafrost beneath the active layer thickens as new frost layers accumulate each winter (Brown, 1970). The average permafrost thickness ranges from less than one meter to 600 meters or more, and for the active layer, between a few centimetres to approximately 10 meters (Davis, 2001). Although permafrost layers have reached over 1000 meters in thickness, it is the heat from the earth's core that stabilizes permafrost thickness by thawing any sub-layer not being affected by the winter freezing. Insulation from snow cover has a similar effect as it increases the permafrost temperature.

Layers of ground that have thawed within permafrost are called taliks (Esch, 1996) (Figure 9.6).

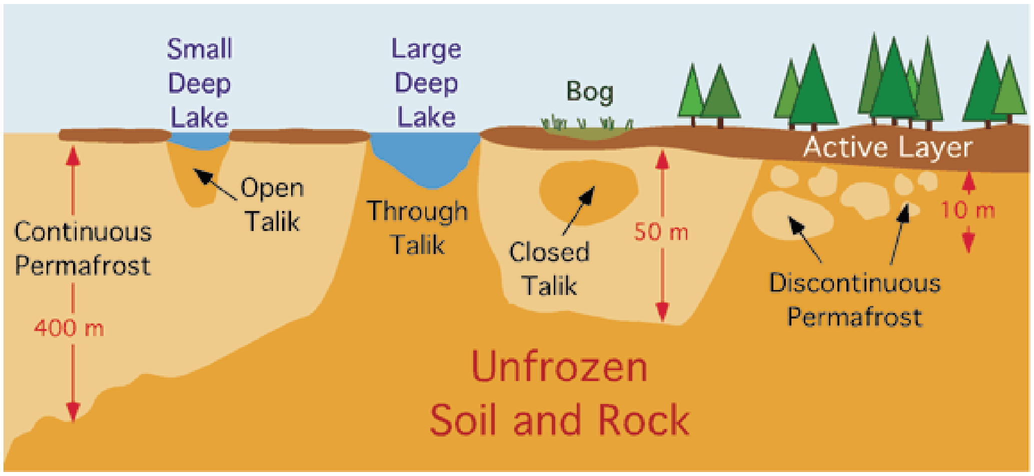

Figure 9.6 An illustration of the different states of permafrost (Pidwirny, 2006).

Permafrost can be discontinuous, where as the name implies, it is found in "patches" surrounded by larger regions of unfrozen ground. Similarly, sporadic permafrost consists of larger dispersed islands of permafrost in regions of unfrozen ground. On the contrary, a constant layer of frozen ground underlies regions of continuous permafrost (Pidwirny, 2006). Half of Canada's land area lies on permafrost, the northern part being continuous and the southern parts discontinuous (Figure 9.7). Even though terrain factors such as vegetation, soil type and snow cover affect permafrost, temperature is once again the primary factor that defines its state and sets apart the two zones (Johnston, 1981).

An increase in the active layer thickness, caused by melting permafrost will cause ground movement in what was once assumed to be strong, frozen, stable ground. Talik zones, ice-rich areas, and other regions where water can accumulate also contribute to this instability because of the change from a frozen to a liquid state. Knowing which areas of permafrost contain ice, or are poorly drained and can become ice-rich, is an essential part of construction engineering in permafrost regions due to the different types of damage that ice is causing to the surrounding infrastructure because of thermokarst and differential settlement. Thermokarst is a land area with an irregular ground ice content, and consequently uneven thaw settlement throughout. An irregular surface with water filled pothole-like cavities is characteristic to such a terrain (Davis, 2001) (Figure 9.8). Other common effects include ground swelling, frost-heaving, damage due to icing, as well as landslides and other unexpected ground movements.

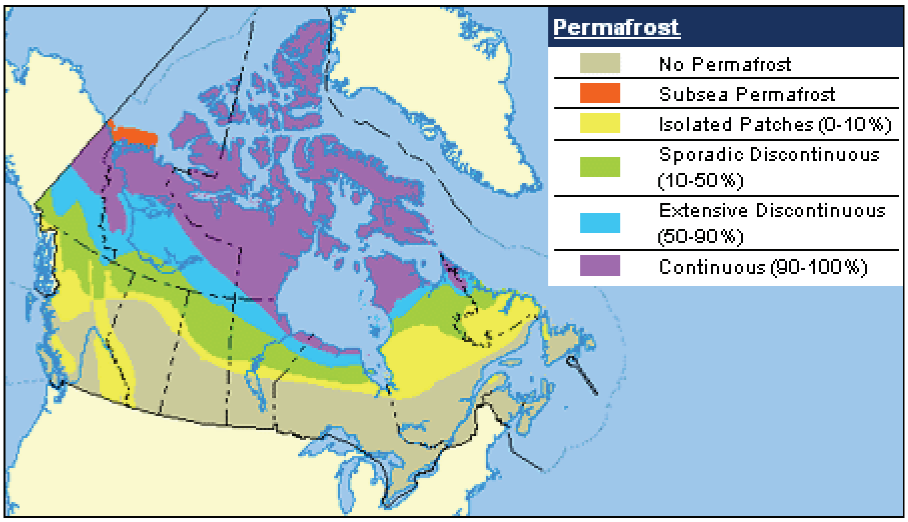

Figure 9.7 Permafrost distribution in Canada (Harris, 1988).

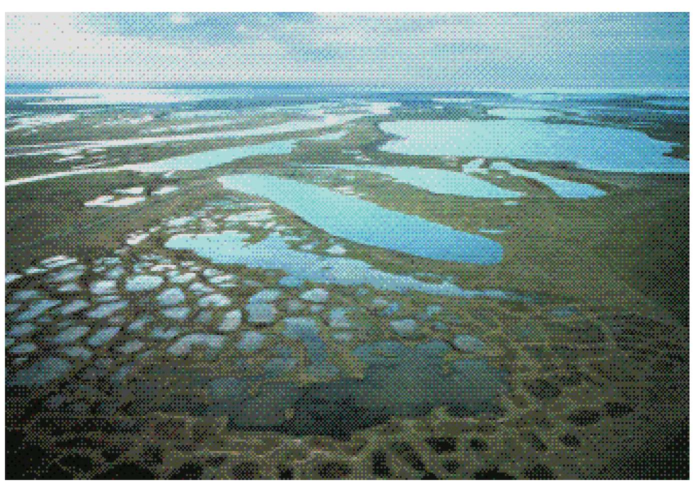

Figure 9.8 Thermokarst terrain (ANWR, 2006).

According to the temperature trends for the last 50 years, the average annual temperature has increased by two to three degrees Celsius in the Western Canadian permafrost zone and by one to two degrees Celsius in the Central and Eastern permafrost regions. Future projections estimate that during the next decade, temperatures in these regions will increase by four to seven degrees and three to five degrees Celsius, respectively (Arctic Council, 2004). Consequently, the active layer thickness will increase and the permafrost layer will decrease, eliminating it completely from some areas (U.S. Arctic Research Commission Permafrost Task Force, 2003).

*9.6.2. **The Impact of Melting Permafrost on Infrastructure: Primary Problems and Engineering Considerations***

Presently, there are 18 highways (Government of the Northwest Territories, 2006) and 11 airports in the Northwest and Yukon Territories alone (Transport Canada, 2006). The construction materials and methods have changed since the late 19th century, and in addition, the knowledge of permafrost has evolved considerably. Many researchers had already noted engineering considerations required in these regions. Building and design methods have changed considerably to reflect the knowledge gained from the problems experienced with some of the earlier infrastructure. Reduction of the ground strength, stability, and therefore ability to support infrastructure is the main concern associated with construction in areas of melting permafrost. Ice-rich permafrost zones - areas underlain by discontinuous permafrost - and regions where taliks are present are of particular concern, as they are most sensitive to temperature increases. Possible impacts on different types of infrastructure include:

Airfields and Roads

- Soil type, water content and ice content of the subsurface, vary from one location to another along the pavement length. Therefore, different locations on one roadway may thaw or be subjected to larger loadings than others. As a result, differential settlements are one of the main consequences of melting permafrost, resulting in uneven surfaces that require prompt remedial measures (Esch, 1996). A paved road in an ice-rich zone, for example, would require regular maintenance or reconstruction before the end of its planned service life.

- Longitudinal cracking is another reoccurring problem on roadways and airfields, because of the differences in the albedo (the radiation reflectivity of a surface) and insulation from the middle to the sides of the road embankment. The albedo, or the ratio of reflected to absorbed light of the side slopes, is lower than that of the flat top portion of the road. In addition, ploughed snow on the sides of the road insulates the side slopes from cold temperatures, subjecting the underlying permafrost layers to more heat and greater thawing (Freitag and McFadden, 1997). Consequently, cracking and settlements occur on the sideslopes, where talik zones form in most cases (Esch, 1996) (Figure 9.9) and increase in size each year due to the climate change. Therefore, knowledge of the type of terrain and climate of the region is vital and will be a good basis for choice of the pavement.

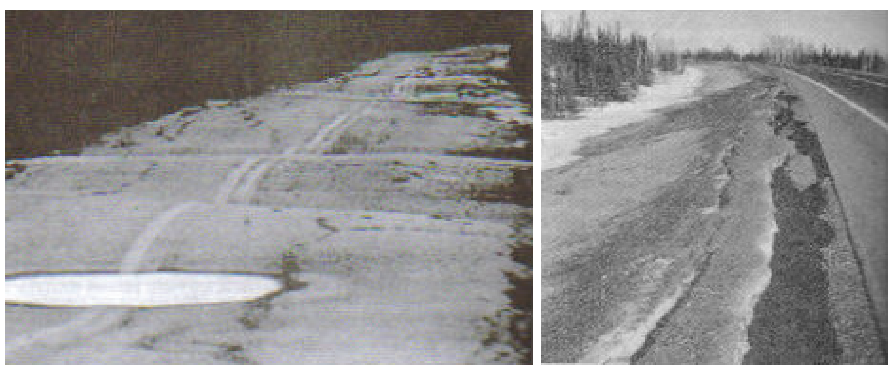

Figure 9.9 Differential settlement of a roadway (left). Longitudinal cracking of roads and airfields (right) (Esch, 1996).

Bridges

- Frost heaving is a phenomenon where ice formation causes an increase in soil volume, which if prevented or restrained partially, leads to upward and outward forces. The causes include unequal load distribution and differences in water content in one particular area (Muller, 1947). These conditions are considered in bridge design, since load patterns and water content can differ from that directly beneath and surrounding the bridge piers, which are usually made of concrete. More heat is generated in the soil beneath the bridge piers because concrete has a higher thermal conductivity than water or snow in between the piers. Consequently, the water from thawing beneath the piers flows to the surrounding areas. In cold temperatures, considerable ice can accumulate, causing heaving, which affects the surrounding piers (Ferrians et al, 1969).

- An increase in air temperatures will help thaw the large ice formations, yet they will also cause large icings to break, resulting in the rise of water levels. Water flowing in newly opened channels under the bridge will move the large pieces of ice at faster speeds. Consequently, large forces and erosion will deteriorate the piers in the way of the moving ice (Freitag and McFadden, 1997).

Buildings

- Buildings often generate enough heat to contribute to the thawing of the underlying permafrost. Therefore, selecting a suitable spread, buried or pile foundation is a critical decision and depends on the intended use of the structure. Buried foundations should be considered for permanent structures with heavy loading and should be constructed sufficiently deep into the ground to prevent excessive heat exchange with the underlying soil. The spread foundation is a good choice where foundation movement will not be a great concern, and should therefore be considered for smaller structures with lighter loads. Facilities that are used temporarily throughout the year, such as certain businesses or research centres, would also be constructed with this type of foundation because temporary heating would not be significant enough to contribute to excessive thawing. Lastly, piles are useful where poor drainage is characteristic to a site (Brown, 1970) (Figure 9.10).

Figure 9.10 Use of piles as a structural foundation (NRC, 2006 on left and KlimaNotizen, 2006 on right).

- Here, the effects of water content are considered since frozen ground is impermeable. Consequently, water may not be able to flow naturally and may accumulate around or between the permafrost where it will undergo freezing and thawing cycles, which can lead to settlement (Davis, 2001) (Figure 9.11). Choosing the right type of foundation is therefore important if, in addition to permafrost thawing due to climate change, heat from structures leads to thawing as well.
- As in this case, locating bedrock for the structural foundation and steering clear of ice-rich zones would be an ideal solution.

Figure 9.11 Examples of buildings destroyed by melting permafrost. Apparent uplift of the right side of building due to frost heaving (left – GSC, 2006). Differential settlement followed by extreme cracking of buildings (centre and right - Brouchkov and Himenkov, 2006).

Hydraulic Structures

- The impounded water from these structures will play a role in thawing subsurface soils over time, but thawing of ice will have an immediate effect. The structure would severely crack in case of large settlement, or it may be completely destroyed in the event of a landslide.
- Settlement or slumping of the ground beneath the structure may also provide a passage for water to divert beneath the dam. With time, this flow will erode the foundation (Ferrians et al, 1969).

Municipal Services

- The scarcity of available sources of water in cold regions is quite troublesome in the planning of municipal services. The fact that services are normally buried underground adds to the challenge, since pipes in permafrost regions cannot be buried beneath a frost depth. The word "normally" can in fact be used in the last sentence, since water distribution and sewage disposal systems may be built above ground in Arctic climates (Figure 9.12).

Figure 9.12 Water and sewage distribution pipes placed in surface utilidors (Town of Inuvik, 2006 on left and Photo Mondiale, 2006 on right).

- Other distribution methods can be seen in Arctic regions: trucked systems, where trucks deliver water that will be stored in storage tanks at each individual home and central watering points, where residents must pick their water supply at a local storage tank (Freitag and McFadden, 1997).

- Buried or aboveground systems are more common in larger, more developed communities; they are more prone to cracking as a result of the climate change. Choosing between a buried or aboveground system is an important consideration in the design process and depends on the climate fluctuations and the soil types found in a given locality. Buried systems are generally found within approximately 5 meters from ground surface, in areas with well-drained soils. In other words, an aboveground or surface system should be constructed where fine soils exist. Here, excess water is impeded from flowing freely and as a result ice lenses can form during the frost season (Brown, 1970). Excessive freezing and thawing of ice surrounding the pipe system, due to temperature increases and heat from the pipes themselves could cause cracking and eventually breakage of the pipe.
- Figure 9.13 shows a pipe being uplifted, which is another problem faced in these regions. Surface systems are preferred and usually built on piles to prevent further contribution to the heat already being exchanged at ground surface, from increased air temperatures.

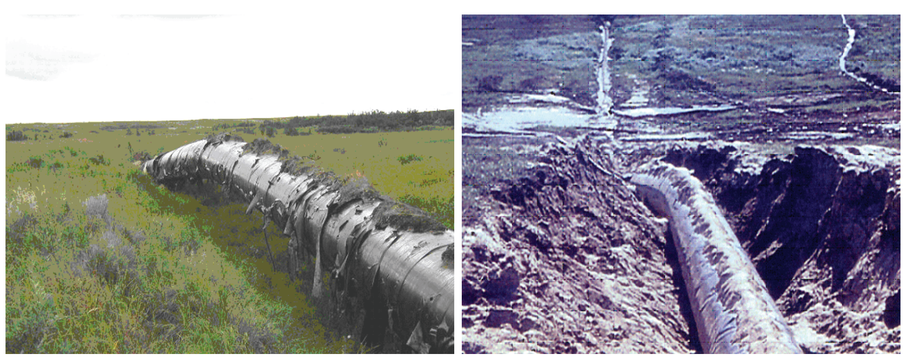

Figure 9.13 Pipe uplift due to frost heaving (Brouchkov and Himenkov, 2006).

CHAPTER 10

A NATIONAL INFRASTRUCTURE POLICY FOR CANADA

10.1 Introduction

Most of Canada's infrastructure was built between the post-World War II period and the 1970's, and most of it has already reached the end of its useful service life. In 2003, more than half (59%) of the infrastructure in Canada was more than 40 years of age; an astounding 28% between 80 and 100 years (Figure 1.2) (TRM, 2003). While many of these older infrastructure assets are in urgent need of rehabilitation and replacement, there are also many newer facilities, along with the older ones, that are deteriorating quite rapidly due to lack of adequate maintenance and repairs over their service lives, which has resulted in a serious backlog needing urgent attention. There are many factors which have contributed to this serious situation, primarily inadequate levels of funding in the area of municipal works, government's failure to acknowledge the looming infrastructure crisis and its failure to act quickly to provide funding for maintenance, and other needs.

There is an urgent need to recognize Canada's serious infrastructure crisis and to regulate and standardize infrastructure management practices across the country. Some professionals have suggested the need for a National Infrastructure Policy (NIP) aimed at addressing the various issues that have caused rapid deterioration of assets and the resulting large infrastructure deficit. A National Infrastructure Policy would ensure a commitment by all levels of government to tackle the present challenges. It will also encourage practitioners and academia to shift from the current 'design'-focused curriculum to one emphasizing "proper maintenance and renewal" of infrastructure.

The issues that have led Canada to the current infrastructure crisis are presented along with a summary of the reasons for the much needed infrastructure policy. Some related examples are briefly reviewed and appropriate mitigation steps are suggested, along with a brief review of the existing recommendations for a National Infrastructure Policy.

10.2 Present State of Infrastructure

In recent years, several infrastructure-related tragedies have occurred in Canada and elsewhere in the world; which include bridge collapses, pipe breaks, water supply contaminations and resulting outbreaks, and transit, rail accidents, etc. The most recent Canadian tragedy was the de la Concorde Overpass collapse in Laval, Quebec on September 30, 2006, causing five deaths and six injuries and considerable socio-economic loss and inconvenience to the community. All of these infrastructure-related tragedies reflect the unacceptable levels of deterioration that have accumulated gradually; this situation must change immediately to ensure adequate and safe functioning of the communities. Many of these tragedies resulted from poor quality control and safety measures during design and construction, and inadequate management and maintenance practices throughout the asset's service life. Consequently, many of these assets are failing well before the end of their expected service lives, posing serious threat to public health and safety, necessitating urgent improvements in Canada's transportation, transit, water supply, sewage disposal and other infrastructure systems. These repair, rehabilitation and replacement activities are needed to augment Canada's productivity, international competitiveness and economic development of the cities, regions and the country, and to improve the quality of life of all citizens.

Public health and safety, and the environment are presently at risk due to the severely deteriorated state of assets and management practices. The infrastructure in the United States is in an equally bad state; the overall state of their infrastructure having been given a failure grade 'D' in the last ASCE (American Society of Civil Engineers) infrastructure report card in 2005. The municipal infrastructure deficit in Canada - the difference between the available funding and the funding needed for maintenance, repair, rehabilitation and replacement of existing deteriorated infrastructure assets - is normally used to evaluate the overall state of assets and to quantify the infrastructure crisis.

10.2.1. ***Infrastructure Deficit***

The 2007 *FCM-McGill Municipal Infrastructure Survey* estimate of the deficit is $123.6 billion for the existing infrastructure owned by the Canadian municipalities to upgrade it to an acceptable performance level. The survey estimated the new infrastructure needs arising from population growth, or replacement of older infrastructure which has deteriorated excessively and cannot be rehabilitated efficiently, to be $115.2 billion. The municipalities who participated in the survey felt that aging of infrastructure, population growth and new environmental regulations are the factors that are contributing most to the compounding of the infrastructure deficit. It should be noted that these estimates are considerably higher than the 2003 upgrading by the Technology Road Map ($57 billion) of an earlier FCM-McGill (1996) deficit estimate of $44 billion to upgrade Canada's municipal infrastructure.

The sub-deficit estimates in the areas of water supply, wastewater and stormwater, transportation, transit, waste management and cultural, social, and recreational facilities are summarized in Figure 10.1; these have increased considerably from the 1996 FCM-McGill Survey findings. The need to upgrade existing cultural, social, community and recreational facilities is the greatest at $40.2 billion, up from the 1996 estimate of $7.55 billion. Most of these needs related to the larger municipalities, such as Toronto and Montreal. The large increase can be attributed to the limited funding available to the municipalities in recent years, which was spent on the more urgent infrastructure categories, other than the cultural, social and recreational assets. The survey results confirmed that water and wastewater systems, transportation and transit infrastructure categories also require significant financing, consistent with the findings of the Canadian Water Network (CWN, 2003-2013), the Canadian Water and Wastewater Association (CWWA, 1997-2012) and the Canadian Urban Transit Association (CUTA, 2008-2012). The financial needs for new infrastructure were not assessed in any past surveys, and therefore, a direct comparison was not possible.

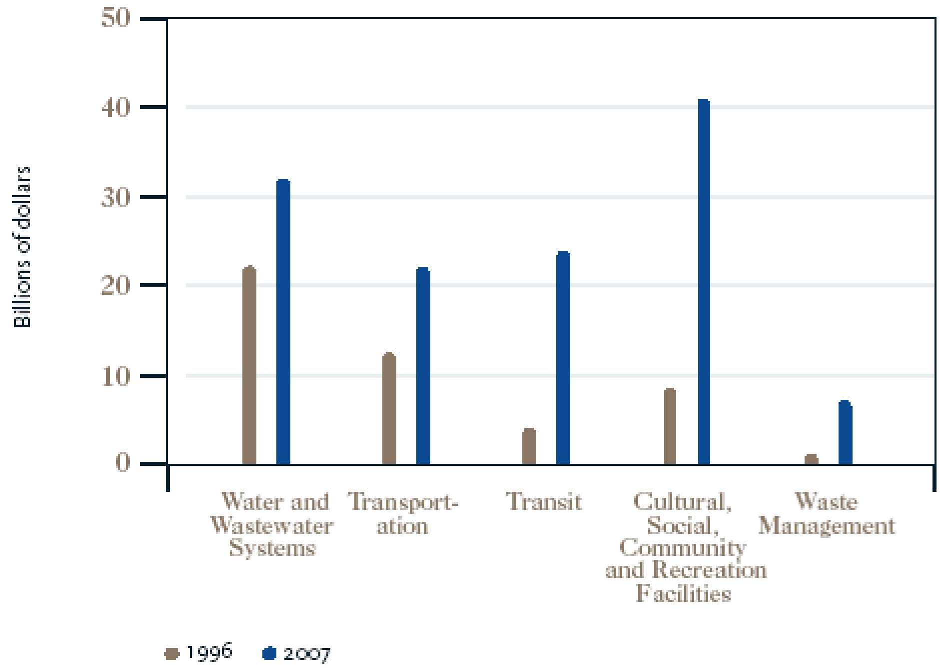

Figure 10.1 Sub-deficits for each main infrastructure category in 1996 and 2007 (Mirza, 2007).

*10.2.2. **Needs of the Municipalities***

Canadian municipalities require much more than just the obvious funding that is needed to bring the existing deteriorated infrastructure up to acceptable levels of safety and serviceability, and to ensure that facilities are upgraded, or that new assets are built to satisfy the new needs. The municipalities, the provincial and federal government, and other public and private organizations could possibly benefit from a National Infrastructure Policy, including some recommended, and innovative funding alternatives, but also scientific asset management practices and implementation strategies.

10.3 Existing Recommendations for an NIP

A series of articles in the 1998 Manitoba Heavy News of the Western Canada Roadbuilders and Heavy Construction Association recommended that a National Infrastructure Policy target three main areas: rehabilitation of municipal infrastructure, the national highways system under a National Highways Program (NHP) and strategic infrastructure investments (SII). At the August 1993 Annual Premiers' Conference (APC), Provincial Premiers and Territorial Leaders supported the idea of a National Infrastructure Policy, urging the federal government to agree with the initiative. However, the literature on the subject suggests that the Premiers and Leaders were in favor of a multi-year policy similar to the 1993 $6 billion shared Canada Infrastructure Works Program (Hengen, 1998). Extending the duration of existing government infrastructure programs would not be sufficient to ensure sustained funding for the country's infrastructure needs, besides being unable to address the many issues that have led to the current crisis.

The Infrastructure Council of Manitoba (ICM) was formed in 1994 to address issues of investment and maintenance of municipal infrastructure, while working in partnership with the various government bodies and public organizations. In 1998, the ICM promoted the need for a National Infrastructure Policy with the major objective of addressing "strategic infrastructure investments from within existing revenues in a sustainable manner which levers matching contributions from other levels of government and/or the private sector" (Hengen, 1998), emphasizing the need for initiatives between both the public and private sectors. In 2000, the ICM recommended to the Canada Transport Act Review Panel that a National Highways Policy be adopted by the federal government, to include minimum design and engineering standards for the national highway system (Infrastructure Council of Manitoba, 2000).

Mirza (1998) urged the adoption of a National Infrastructure Policy of a much wider scope. As stated by Mirza "it is imperative that the public and private sectors realize that a National Infrastructure Policy is as important to the future of Canada as our present and projected needs in areas of health, education, social safety net, youth training, research and development and debt/deficit reduction at all levels of government" (Mirza, 1998). He has continued to make the case for a National Infrastructure Policy (Mirza, 2006).

The Canadian Council of Professional Engineers have backed the idea of a National Infrastructure Strategy and sustained funding (2006); the Canadian Automobile Association strongly supported the need for a National Highway Plan (CP Wire, 2006). In summary, there is a broad support among professionals and professional organizations for a policy to address the infrastructure shortfalls and future needs in Canada. However, the support and action by the political leaders has been missing and infrastructure issues have not been on the platform of any political party, contesting the national or provincial elections over the past several years, excepting for the Federal Liberals in 1993, and the Ontario Liberals in 2008.

10.4 Developing a Policy Framework

According to Howes and Robinson (2005), the following issues need to be resolved to successfully implement an infrastructure policy:

- Goals and objectives must be defined in developing the policy, followed by their effective implementation by all parties involved;
- Institutions to ensure coordinated implementation and a central source of information for public and private sectors;
- Needed Resources - monetary and professional personnel - engineers, planners, legal and financial specialists, environmental and safety specialists, etc.
- Knowledge: expertise in different areas, including political, technical, financial, etc.;
- Information and communication systems to improve communications and provide an organized framework between the various parties involved.

Finally, an environment must be created where professionals, and related groups and organizations evaluate and understand the economic, social, environmental and political influences driving the needed policy, and ensure that these are reflected in its development along with the needs related to sustainable development. In other words, besides technical issues, socio-economic, political and environmental impacts of the current crisis should be addressed in the infrastructure policy.

10.5 Basic Issues

Some examples highlighting the shortfalls in the planning and management of infrastructure are summarized in Table 10.1. The issues needed to be addressed in the policy are briefly presented and appropriate techniques are recommended in each case.

Table 10.1 Issues for consideration in a proposed National Infrastructure Policy.

Basic Issues	Examples	Needs/Proposed Mitigation

Deferred maintenance and non-routine inspections	▪ Primary causes of bridge collapses that have occurred since the 1970's
	▪ De la Concorde Overpass (Laval, Quebec) collapse in 2006:
	    ▪ Collapsed after only 36 years in service
	    ▪ Deferred maintenance partly to blame
	    ▪ Also collapsed due to quality control issues
	▪ Minnesota Bridge collapse in 2007:
	    ▪ Failed after 40 years
	    ▪ Officials warned as early as 17 years prior that the bridge was "structurally deficient"
	    ▪ In those 17 years, only small scale repairs and inspections were performed.
	    ▪ Two years prior to the collapse, the Department of Transportation had repeated these warnings, urging more frequent and more detailed inspections of the bridge trusses (Keen, 2007)
		▪ An urgent need to ensure that, under no circumstance, should maintenance ever be deferred
		▪ Applies to all infrastructure - large-scale deterioration noted on many asset types across the country
		▪ Accumulated degradation of the aging assets has led to rapid escalation of the infrastructure deficit

Lack of life-cycle performance and cost analysis in the initial project planning stages, complete with valuation, depreciation and risk	▪ The lack of available funds for the present routine maintenance of assets is partly to blame for the severe infrastructure degradation, and for the escalation of the infrastructure deficit over the years. If life-cycle costing had been implemented, funds would have been reserved for these much needed practices	▪ Adopting legislation and policies that require life-cycle performance and costing to be considered:
		    ▪ In the bidding process
		    ▪ In the planning stages of all projects
		▪ Such practices should be supported by an infrastructure asset-management system (IAMS)
		▪ Will prevent cost overruns and ensure that funding is available for future routine upkeep, rehabilitation and replacement of the assets when needed, to

Table 10.1 (Continued)

assessments		comply with the definition of sustainable development ▪ Will shift the current mentality of "design, build and forget" to one of "design, build and maintain"

Insufficient levels of investment in the area of infrastructure, particularly for maintenance and upgrading needs	▪ The $33 billion *Building Canada Plan* (2007-2014):
	  ▪ $17.6 billion, will be allocated to the municipalities; over seven years, the municipalities will receive approximately $2.5 billion per year – it is not specified whether this is to meet upgrading or new needs
	  ▪ The latest *FCM-McGill Municipal Infrastructure Survey* estimates the municipal infrastructure deficit to be $123.6 billion, in addition to the $115.2 billion needed for new infrastructure. Therefore,
	  ▪ the funding available under the seven year plan is highly inadequate
		▪ It is essential to re-evaluate the infrastructure financing
		  ▪ More innovative and sustainable sources of financing are needed
		  ▪ A significant highlight of the $33 billion plan is that a P3 office will be established, encouraging the use of P3s as an alternative
		  ▪ Strategic investment in infrastructure in upcoming government budgets and allocation of funds from the yearly surplus
		▪ In addition, an Infrastructure Bank should be established, similar to those already established in some States
		  ▪ Repayments are recycled in the infrastructure bank for future projects
		  ▪ Would ensure a sustained funding source
		  ▪ Short-term infrastructure programs are only complementary. Therefore, if a government program expires, funds are always available to meet the upgrading and new needs
		  ▪ Operation of the bank would include project application and selection process to fund selected projects from the

Table 10.1 (Continued)

		capitalization reserve through low-interest loans and credit enhancements

Short-term government funding programs	▪ The $6 billion *Federal Infrastructure Works Program* (1993-1998):
	  ▪ A joint partnership between the three levels of Government that ran only for six years
	  ▪ Helped fund 12,000 projects and created 10,000 jobs (Government of Newfoundland and Labrador, 1997)
	▪ While the program did have its faults (i.e., 60% of spending was related to new infrastructure, though one of the initial objectives was to upgrade the municipal infrastructure), the general consensus among municipalities was that the program helped to improve the state of infrastructure in Canada (Siddiqui, 1997)
	▪ The success of this program was unfortunately short-lived
		▪ An infrastructure bank for Canada

Lack of a complete inventory of all assets in Canadian municipalities	▪ Projects have been prioritized and funding has been allocated inadequately in many cases, due to lack of a complete inventory of all assets. For example:
	▪ The Highway Improvement Program (1993-1998)
	  ▪ Funding was proposed in 1997 under this program, to upgrade segments of the National Highway System that were initially recorded as being "acceptably smooth" and "over the acceptable engineering standards for surface roughness" – information that was obviously not provided to investment planners
	  ▪ Funds were being allocated to improve stretches of highway that already had funds approved for them
	  ▪ The Auditor General expressed concern that allocated funds may have been used to meet cost overruns
		▪ Municipalities should be required to keep a complete inventory of all assets, which would enable more accurate and effective funding allocations and project prioritization
		▪ Inventory should be complete with condition assessment information, construction specifications and upgrading/maintenance history
		▪ All of the above information should be provided to planners during budget allocations

Table 10.1 (Continued)

	rather than to achieve new program objectives (Ruta et al, 1998), which could have been prevented, if information about the segment's maintenance and financing history, and its condition were available	

The need to implement standardized AM practices across the country and focus on long-term planning	▪ If one municipality groups sewer systems and stormwater systems in one classification, it is difficult to compare the needs of other municipalities who keep records of both asset types separately. This increases the difficulty of adequately prioritizing needs
	▪ The City of Edmonton has addressed this issue as follows:
	  ▪ The City applies a condition rating scheme based on letter grades (A – Very Good, B – Good, C – Fair, D – Poor and F – Very Poor)
	  ▪ The physical condition, functionality and demand/capacity are rated with these letters
	  ▪ The City "translates" asset-specific condition ratings already employed by specific departments (e.g., the use of a Pavement Quality Index by the Transportation and Streets Department), by defining conversions between ratings within a computer application (Cloake and Siu, 2002), providing for more integrated planning between the infrastructure categories and the various departments
	▪ The City of Edmonton is also a leader in long-term planning approaches. Through its Office of Infrastructure (2000), the City of Edmonton maintains a complete inventory of all assets and financial data, and has developed a risk assessment methodology and a life cycle costing protocol, among other practices that should be adopted nation-wide
	▪ The Australian literature also reveals that, state manuals and information systems vary as for the U.S.A., making it difficult to
		▪ Use of a common Infrastructure Asset-Management System (IAMS) that should:
		  ▪ Support standardized data recording/inventory tracking across the municipalities and facilitate long-term planning
		  ▪ Support essential practices in long-term planning: life-cycle costing and analysis, condition tracking, valuation and depreciation of assets, the calculation of remaining service life, risk and performance assessments, project prioritization based on numerous factors, etc.
		  ▪ Be customizable in some ways to account for varying demographics, environmental conditions and new regulations, population growth, activities/lifestyles, local needs, etc. For example,
		  ▪ The system should support the management of different types of assets in different Canadian regions (e.g., trams, ferries, a metro system, etc.)
		  ▪ Include a condition rating module that is able to convert the municipality's condition ratings to a standard rating used across

Table 10.1 (Continued)

	co-ordinate management practices at the state and the national levels (PSAB, 2007)	the country, like the City of Edmonton
Failure to consider sustainability in all phases of project planning (feasibility studies, design, construction, maintenance, decommissioning, etc.).	▪ Failure to account for sustainable development can come in a variety of ways: ▪ Not performing life-cycle costing analysis (LCCA) ▪ Not trying to cut down on wastes in the construction and decommissioning of assets is another example, as around 30% of the waste generated in Canada comes from the construction industry, including the waste generated by renovation and demolition practices (Catalli, 1999) ▪ Failure to account for energy saving alternatives or to consider options for water conservation in the design of facilities ▪ Failure to seek "greener" construction practices where possible (e.g., trenchless technologies)	▪ Incorporate the four 'R's – reduce, reuse, recycle and rethink – in all practices ▪ Sharing best practices to encourage the implementation of sustainable practices in the design, construction, maintenance, management and operations of all infrastructure types: ▪ LCCA ▪ Waste reduction ▪ Quality control ▪ Environmental considerations ▪ A shift to "greener" construction practices
Little consideration for climate change in the design of new infrastructure and in the retrofitting of existing infrastructure	▪ New stormwater sewers should be designed with greater capacity to be able to remain serviceable in periods of intense rainfall and for the predicted increase in winter precipitation ▪ Otherwise if the stormwater system reaches over-capacity, sewage can overflow, by-pass the water treatment plant and be discharged into freshwater sources without the required levels of treatment	▪ Further research and development of the impacts of the climate change crisis on infrastructure ▪ Environment Canada has made tremendous progress in modeling predicted future weather extremes. There should be more communication between civil engineers and environmentalists to highlight how these weather patterns can impact the different infrastructure systems ▪ There should be documents made available to practitioners, highlighting the needed design considerations

Table 10.1 (Continued)

		▪ Climatic data used to calculate wind, rain and snow loads, and temperature design values in the design codes should be modified to represent predicted weather patterns

10.6 National Infrastructure Policy

A National Infrastructure Policy for Canada must be aimed at:

- Acknowledging and alleviating the infrastructure crisis and its associated social, economic, political and environmental impacts;
- Repairing, rehabilitating and replacing existing severely deteriorated assets and establishing routine maintenance plans for all future construction;
- Eliminating the infrastructure deficit and the associated sub-deficits for the main infrastructure categories;
- Establishing a commitment by the three levels of government to overcome the infrastructure crises at the municipal, provincial, territorial and national levels;
- Ensuring that the private sector implements the recommended best practices and conform to associated legislation;
- Shifting the industry towards more sustainable practices and ensuring that these practices continuously adapt to the emerging environmental and climate change issues;
- Encouraging the Universities and technical schools to make changes to the civil engineering curricula, to place increased importance on educating future graduates on aspects of deterioration, renewal, infrastructure management and more sustainable practices;
- Providing practitioners across the country with updated, standardized best practices;

A National Infrastructure Policy for Canada would ensure that:

- The infrastructure crisis be acknowledged as a critical, national problem that must promptly be addressed;
- All three levels of government increase their level of investment in infrastructure;
- Maintenance and inspections shall never be deferred;

- Quality control be of utmost importance in all aspects of infrastructure design, construction, maintenance, operation, etc.;
- A detailed inventory of all assets be maintained to include technical, financial, and maintenance and other construction-related information;
- Scientific AM becomes common practice;
- An IAMS that supports long-term planning in addition to routine management practices, be available for implementation of AM techniques;
- That the IAMS, standardized inventory tracking and long-term assessments (risk assessments, value engineering, LCCA) support fair and strategic project prioritization and funding allocations;
- All government funding programs are to be complementary to a sustained funding source, available through an infrastructure bank;
- Technical, socio-economic, environmental and health risks be considered, in addition to population, when allocating project funds;
- LCCA be made mandatory prior to the approval of all projects;
- LCCA should include asset valuation and depreciation, and risk assessments;
- The appropriate financing alternative be selected based on the criteria of efficiency, equity, effectiveness, environmental sensitivity, innovation, accountability and administrative costs;
- Sustainable development be encouraged in all phases of a project;
- The repair and rehabilitation of existing assets be considered an opportunity to retrofit existing assets to resist the expected climate change extremes, and that climate change be similarly considered in the construction of new assets;
- Funds not only be directed towards improving the state of infrastructure assets, but that they be used to help develop and implement standardized practices, develop offices to aid in the implementation of a national policy, education and awareness campaigns and establish the recommended IAMS and infrastructure bank;
- Further research and development in each of the above-mentioned areas;
- Increased collaboration and interdisciplinary group work to be undertaken among engineers, urban planners, social scientists, politicians, economists and

environmentalists to progress in eliminating the infrastructure deficit and the crisis, while catering for the present-day issues such as climate change, escalating oil prices, etc.;

10.7 National Benefits

There are several, obvious benefits of dealing with each of the above-mentioned issues. It must be emphasized that nation-building, international competitiveness and a superior quality of life cannot be maintained without safe and serviceable infrastructure to support everyday activities and the services essential to sustainable development and human survival. Addressing these issues with a National Infrastructure Policy poses its own benefits, namely:

- Assurance that changes are made across the country, thereby equitably promoting development nation-wide;
- Facility for the public and private sectors to adapt to a policy that incorporates the various issues, rather than adapting to the different policies that may be developed at different times, especially when many of these issues are inter-related and should be dealt with simultaneously. For example:
    - The need for improved AM practices encompasses the needs for LCCA, inventory tracking, risk assessments, etc.
    - In turn, funding allocations will be ameliorated with the information provided by a complete inventory of all assets and the information provided by these AM practices;
    - Eliminating the common trend of deferring maintenance goes hand in hand with performing LCCA and considering innovative funding alternatives, which in turn promotes sustainability;
    - Developing AM practices that support long-term planning would be incomplete without climate change considerations, which promote a longer asset service life and ensure that new assets will not need to be retrofitted in the future to meet the demands of the predicted climate changes;

- Finally, innovative funding mechanisms would not only help provide funds for upgrading and new infrastructure needs, but would also ensure that funds are available to perform each of the above-mentioned AM practices.

Most importantly, without legislation to ensure that needed practices are performed, assets will continue to deteriorate, age rapidly and pose serious threats to communities. The society does not need any more infrastructure-related tragedies for the lack of implementation of a national infrastructure policy.

10.8 The Role of Infrastructure Canada

Infrastructure Canada was established in 2002 by the Government of Canada, to work with the different levels of government and the private sector to improve communities across the country by improving safety and serviceability of their infrastructure. Infrastructure Canada continues to aim at improving investments in infrastructure, supporting management and knowledge-sharing with new management technologies and online publications, and through on-going research to identify the infrastructure gaps and priorities, and to propose mitigation strategies and suitable infrastructure programs. With the collaboration of other public and private organizations, industry and academia, Infrastructure Canada continues to move forward with its Research and Analysis Division "to ensure that a more comprehensive knowledge foundation is in place to support and inform policy and decision making" (Infrastructure Canada, June 3, 2008). The main departments within Infrastructure Canada are summarized in Table 10.2.

The list of partial responsibilities provided in Table 10.2 does not highlight several of the contributions made by Infrastructure Canada. A prominent contribution involving Infrastructure Canada, the Federation of Canadian Municipalities (FCM) and the National Research Council is the InfraGuide, a compilation of best practices and guidelines comprising case studies from Canada and internationally. The InfraGuide introduced decision makers and practitioners in the public and private sectors to innovative tools for more effective decision-making, financial planning, and technical expertise, through various publications for the different infrastructure categories. However, this program, which began in 2001, was abandoned in 2007 due to funding being discontinued for this program; the government has turned this into yet another program with short-term vision, similar to the many unsustainable government funding programs.

Table 10.2 The main branches of Infrastructure Canada (information summarized from Infrastructure Canada, June 1, 2008).

Department	Primary Responsibilities
Policy and Communications	▪ Issue identification and assessment ▪ Research ▪ Knowledge sharing ▪ Communication of mandate ▪ Coordination of federal communications of infrastructure ▪ Assistance to the Deputy, who provides policy advice to the minister
Program Operations	▪ Program implementation ▪ Management of infrastructure funding agreements ▪ Program evaluations complete with risk management and environmental considerations ▪ Management of the Federal Gas Tax transfer to municipalities
Corporate Services	▪ Support and service to procurement, IT, human resources, finance, security, and planning and administration departments ▪ Internal audits and evaluations ▪ Support and service to the Shared Information Management System for Infrastructure (SIMSI)
National Transit Strategy	▪ Newest department ▪ Development of a National Transit Strategy in collaboration with Transport Canada

10.9 Infrastructure Australia

While different in many ways (especially in climate), the diversity, size, and activities of Australia and Canada make both countries quite similar in many respects. The fact that both countries are experiencing a looming infrastructure crisis adds to the list of commonalities. The way both countries are dealing with this crisis, however, is quite different, as the Australian Government has adopted a sustained plan to help eliminate the infrastructure crisis.

The example of the Australian Government's latest initiative – Infrastructure Australia – serves as a perfect model of a framework that addresses the various needs in Australia: interdisciplinary infrastructure planning, a commitment to rehabilitating severely deteriorated assets based on established priority levels and guidance for the politicians when it comes to making infrastructure-related decisions. Many of these issues are common with Canada. Infrastructure Australia, a statutory advisory council established in January 2008, comprises 12 members from industry (5 members are from the private sector), government and local government. The objectives of the council as promoted by the Hon Anthony Albanese, Minister for infrastructure, transport, regional development and local government, and the Hon Kevin Rudd, Prime Minister are to:

- Conduct audits of transportation, water, communications and energy infrastructure assets among other main infrastructure types, to help determine which assets have the greatest needs. Australia has an estimated $90 billion infrastructure deficit, as established in 2007 (Dunlop, 2008);
- Develop an Infrastructure Priority List from the audits, which will help prioritize major projects and help appropriately allocate funds;
- Provide advice and guidance to government and private investors regarding innovative funding sources, allocation of funds, planning, project prioritization, future needs, etc. (The Hon Anthony Albanese MP and the Hon Kevin Rudd MP, 2008); and
- Standardize project approval techniques, tender processes, and planning and approval processes across the nation (The Hon Anthony Albanese MP, 2008); etc.

10.10 Implementing an NIP in Canada

The Government of Canada must ensure that Infrastructure Canada has the resources needed to develop and manage sustained infrastructure programs and that they are given greater authority in making infrastructure related-decisions, particularly funding allocations and project prioritizations. Discontinuing the InfraGuide, which was a step in improving and standardizing practices across Canada, shows that this is currently not the case. As mentioned earlier, Infrastructure Australia (IA) is an example of good governance, which if appropriately adopted in Canada, could result in improving infrastructure management and the state of Canada's assets. Although it may take years to successfully operate and produce visible results, IA is also an example of an initiative that was taken by the Government of Australia immediately after its election to help alleviate the severity of their country's infrastructure crisis.

Development and implementation of a National Infrastructure Policy (NIP) would be a useful first step in developing a national commitment among all levels of government and the private sector to standardize fundamental aspects of infrastructure management (i.e. condition assessment, inventory keeping, project prioritization, maintenance practices, etc.) and to eliminate Canada's large infrastructure deficit, which concur with the objectives of Infrastructure Canada and the work of the FCM and the NRC among others. Creating a statutory council such as Infrastructure Australia would be a first step in the implementation of a national policy and could be an added branch in Infrastructure Canada's hierarchy. An ideal hierarchy is depicted in Figure 10.2. The proposed modification to the current structure of Infrastructure Canada would be to develop a National Infrastructure Policy (NIP) Implementation Office as an additional branch to those listed in Table 10.2.

In addition to ensuring that the National Infrastructure Policy is integrated with the public and private sectors, this branch could be responsible for overseeing funding allocations and project prioritizations. These should be based on a detailed priority list of the assets established through audits of the different infrastructure categories, similar to the procedure being carried out by

Infrastructure Australia. The needs should be prioritized based on life-cycle performance and costing, and risk assessments, records of maintenance and upgrading activities and information related to the socio-economic impact posed by the assets (e.g., breakage rate in pipes, or the rate at which the state of a transportation system has been the cause of an accident). The challenge will be to introduce such practices to the public and private sectors while trying to establish a more complete and detailed inventory of the assets. Another implementation strategy could be to present the public and private sectors with an incentive to implement policy guidelines, such as considering the municipality's or private firm's commitment to implementing policy guidelines during funding allocations for new projects. This not only provides an incentive, but also honors their civic duties.

The proposed branch would immediately resolve some of the major issues that are currently placing a barrier on successful infrastructure management, which include:

- Limited interdisciplinary planning and decision-making between parties such as engineers working for the public and private sectors, politicians, urban planners, economists, social scientists, environmentalists, etc;
- Uninformed politicians who often base their infrastructure planning and decision-making on economic and political factors as well as the opinions of society, rather than principally taking technical data and risk analysis into consideration;
- Inequitable funding allocations, as rural communities are often in the position of competing with larger communities for funds, since allocations are not based on the detailed criteria proposed above;
- Short-term vision when developing funding programs, which leaves local governments with limited long-term planning capabilities; and
- The lack of standardized practices, such as project planning and prioritization, etc., across the country.

The proposed NIP Implementation Office would hold responsibilities similar to Infrastructure Australia, by guiding the federal government in all infrastructure planning and financing decisions. This Office would therefore be the link between Government and each of the proposed Provincial/Territorial Implementation Offices, which would also consist of interdisciplinary groups of professionals. These Offices would therefore be representative bodies for the provincial and territorial governments, acting as sources of communication between the first proposed Office and the local governments of each of the provinces and territories. Figure 10.2 provides additional details of the responsibilities of each Office, along with the addition of regional offices, as the Provincial/Territorial offices need to ensure that local governments follow the standards outlined in the National Infrastructure Policy.

Figure 10.3 shows the breakdown of the NIP Implementation Office into two separate branches:

- An Implementation department to provide an information source and support centre for practitioners;
- A Statutory Council that provides guidance to the politicians and makes decisions based on the information received by the other offices;

Figure 10.3 also shows the relationship needed between the above two groups and the following:

- The existing Research and Development team at Infrastructure Canada to help the NIP Implementation Office make factual and relevant decisions, and also to ensure that the Research and Development team's work remains coordinated with the needs of practitioners.
- Lastly, it is suggested that a strong liaison should be established between the proposed Canada Infrastructure Bank and the NIP Implementation Office, though it is recommended that the bank be a separate entity from this Office and Government.

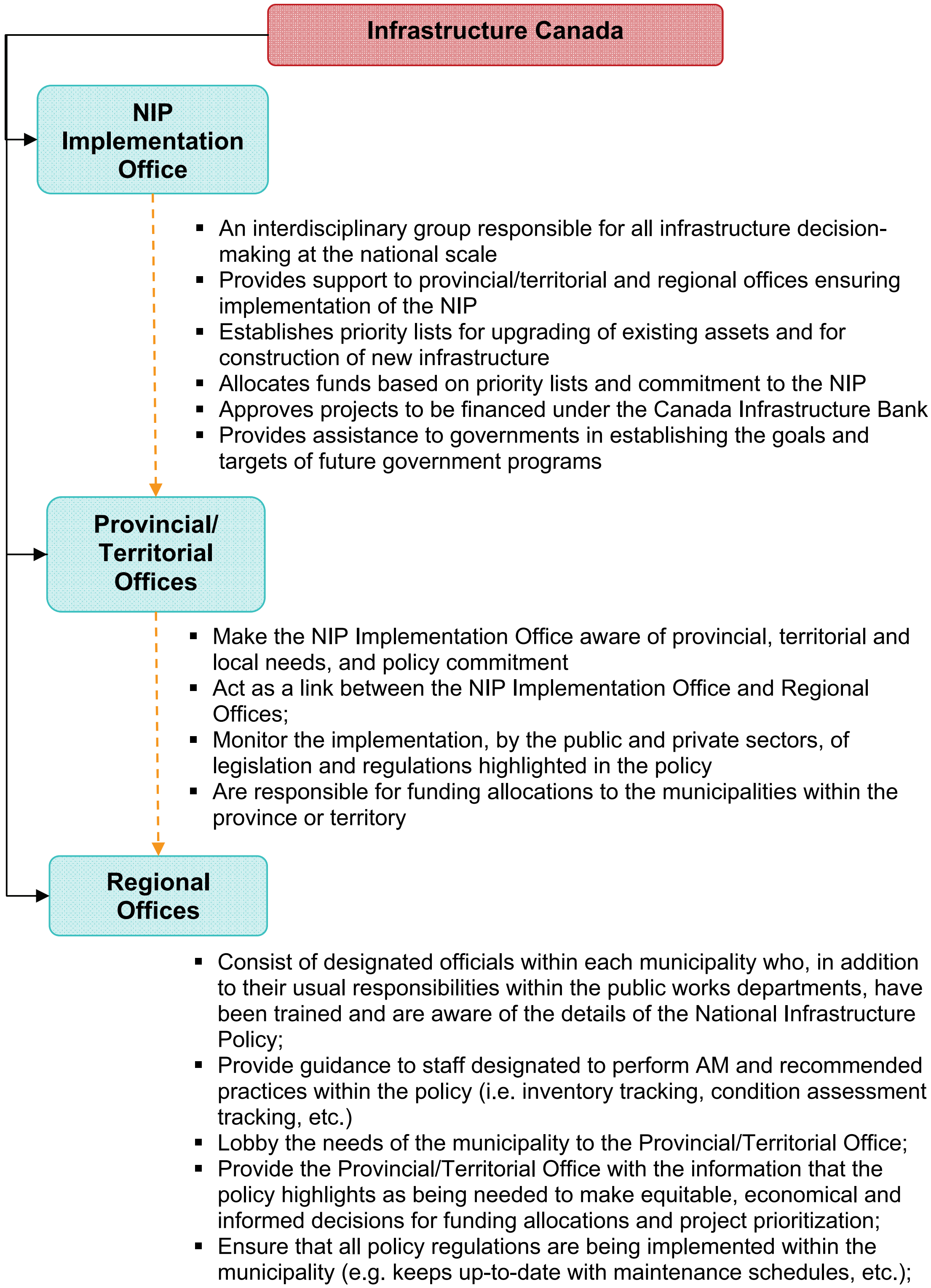

Figure 10.2 A proposed hierarchy for successful NIP implementation under Infrastructure Canada.

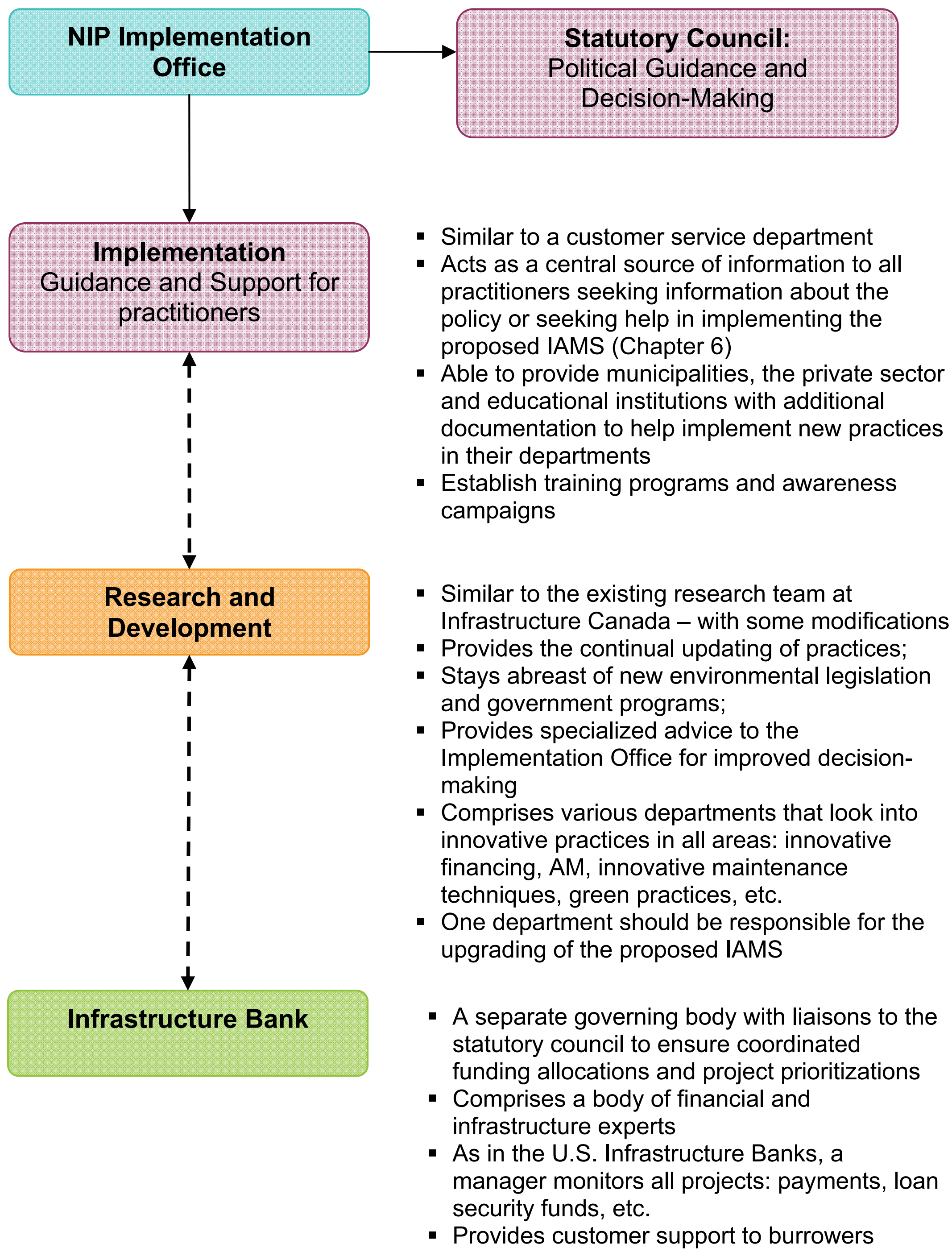

Figure 10.3 Proposed structure breakdown of the NIP Implementation Office and its affiliation to other proposed branches.

10.11 Implementation Needs: Where Do We Go From Here?

It is understood that to simply eliminate the infrastructure deficit can take many years. Similarly, the needs in adopting an infrastructure policy can only be accomplished over several years, with the following tools.

10.11.1. ***Best Practices***

It is essential that the required tools are available to practitioners to effectively manage infrastructure. Organizations such as the National Research Council, Natural Resources Canada, Infrastructure Canada, the Federation of Canadian Municipalities, the Canadian Public Works Associations and the academia have expertise in the various areas of infrastructure, such as the best practices for AM, condition assessments, etc. However, resources and supporting legislation are needed to have these experts develop the protocols necessary for improved infrastructure management practices. The InfraGuide can be considered a stepping stone from which researchers can develop updated and new best practices and the modeling of information systems to support these practices. The best practice guidelines and the associated protocols would have to be continually updated to fulfill the new needs imposed by the population growth, climate change, new environmental regulations, suburban sprawl, etc.

10.11.2. ***Resources***

As mentioned earlier, strategic investments are needed in the near future to ensure that more funds are being directed to the upgrading of the severely deteriorating assets, and to help improve the technical expertise and practices that support sustainable infrastructure management. Establishing the proposed NIP Implementation Office and its affiliated departments and institutions would require a considerable investment and effort. Funds will also be needed for implementation, training and education of the needed new personnel and the municipalities. This initiative can have many long-term economical benefits:

- Tens of thousands of jobs will be created due to the establishment of the proposed Offices and the Infrastructure Bank, and in the related areas of public works;
- Strategic allocation of funds will be encouraged with improved project prioritization and a detailed inventory of all assets;
- Routine maintenance will prevent deterioration from reaching unacceptable levels that often require the asset to be replaced at much higher costs at an early age than the costs needed to perform maintenance on an annual basis;
- Development of a GIS-based inventory and implementation of the needed maintenance and rehabilitation programs will lead to considerable savings of resources and time, and to eliminate or at worst minimize infrastructure-related tragedies;

10.11.3. ***Education and Awareness***

The initial development stages of a National Infrastructure Policy and an Infrastructure Bank can only be successful with the support from all sectors, including the public and academia.

10.11.3.1. Public Awareness

Grey County, Ontario, with a population of 60,000 residents, is one example of a community which has attempted to ensure that the public stay abreast of infrastructure rehabilitation projects around the county. In particular, Grey County initiated the *Closed Loop Tire Recycling Project* in 1993, a program that utilizes used tires as a recycled material in asphalt pavements. Grey County discovered many advantages of rehabilitating severely deteriorated roads by adding recycled tires in the asphalt mixture, while counteracting the environmental and health threats of the county's scrap tire problem. Of course, the project would help any residents wishing to discard their tires, however, the local residents committed to such an initiative.

The end product encourages this commitment: joggers feel less impact on rubberized asphalt, horses are said to speed up when they reach the stretch of this new road and this initiative is highly supported by those who realize that there are many safety, health and environmental concerns posed by severely cracked roads and the scrap tire problem. The Closed Loop Program represents an excellent example of communications, however, the public needs to be convinced of the benefits of the solution.

Informing politicians, landfill owners, dealership owners and residents was an essential part of this program. When it was first introduced, the community was made aware of the details of the project, as well as its benefits through advertisements and public presentations. Reluctant tire dealers were soon persuaded to become committed contributing companies and were highlighted on posters showing their environmental commitment. Billboards now line the streets constructed under this program, leaving no unanswered questions pertaining to the costs and other specifications of the rehabilitation projects. This project has measured the commitment of the community in making it more sustainable.

Implementing a National Infrastructure Policy is a task that is more complex than formulating a pavement rehabilitation program, and will certainly have its share of sceptics – especially with the inclusion of an infrastructure bank. As seen in Section 4.1.1.4 – *User Pay Models*, even after the recent infrastructure tragedies in Quebec, opposing views from Quebecers about user pay models such as tolls and watermeters still exist. The comments provided by the respondents of the *2008 Municipal Infrastructure Public Questionnaire* show that this is due to lack of trust in the Government's willingness to appropriately allocate funds from these user pay models to the principal causes. Public awareness campaigns at all stages of policy implementation would be needed to convince the population that their tax-dollars and the Government commitment are heading in the right direction.

10.11.3.2. Academia

Presently, unless a specific course on the subject matter is taken by students, different forms of deterioration, condition assessment, and repair and rehabilitation techniques are barely covered in the civil engineering curricula of some universities. Similarly, unless students take a specific course which deals with the design of water supply systems, for example, they will not be introduced to the software necessary for the design and inventory tracking of the system. Even if they are introduced to the software, there is no guarantee that the students as future practising engineers will use similar software due to the variability of management systems across the country, or even across a city, and the fragmented and slow process of updating the curriculum. If a national policy would introduce standardized condition assessments and other practices, universities would have to include these in the civil engineering curricula and that of other associated professions dealing with public works. It is recommended that additions should be made to the civil engineering curriculum:

- Deterioration sciences, standardized condition assessment, and repair and rehabilitation techniques for the various infrastructure categories should be taught to the students in an undergraduate infrastructure course;
- The National Infrastructure Policy should be included in addition to regular course material to familiarize the students with its contents;
- Students should be introduced to standard management systems that incorporate the various management sub-systems for different infrastructure types;
- Important economic and political concepts should be taught, in addition to life-cycle performance and costing, depreciation and valuation techniques and optimization strategies, and risk assessments;
- Students should be exposed to the socio-economic, environmental and sustainable development considerations that should be considered in practice; and

- Finally, a special graduate level program dealing with different fields, related to infrastructure, could be quite beneficial, if it is designed to train students to aid in NIP implementation and developing the associated strategies, through an appropriate internship program.

Developing the proposed offices with each level of government will require a high number of trained personnel. The latter program would have to continuously be updated to stay abreast of current political, economic and legislative changes. The program will additionally prepare students from different fields by educating them in fields, other than their own. For example, the curricula would be designed so that all students would learn about the political science, economics, management and engineering issues associated with infrastructure, regardless of their original field of study. While someone who has studied in an engineering program would be better suited to tackle more technical problems in the future, introducing these students to basic fundamentals and concepts from other fields will provide the student with the tools and knowledge needed to cooperate with council members and others in a more informed and decisive manner.

CHAPTER 11

SUMMARY AND CONCLUSIONS

A National Infrastructure Policy (NIP) needs to be developed in Canada as a national commitment by the three levels of government and the private sector, to eliminate the infrastructure crisis and the associated infrastructure deficit. The policy must address the issues that have caused severe deterioration and aging of assets, escalation of the infrastructure deficit and a history of infrastructure-related tragedies in Canada over the past several decades. The policy must also address infrastructure financing, asset management, sustainable development, climate change and, more specifically, the technical, political, socio-economic, and environmental aspects of infrastructure planning.

Section 10.4 – *Developing a Policy Framework* outlined the recommended criteria that must be met to successfully implement an infrastructure policy, according to Howes and Robinson (2005). These criteria have been met with the proposed policy:

- <u>Goals and objectives</u>: A National Infrastructure Policy is aimed at eliminating the infrastructure crisis and deficit by rehabilitating severely deteriorated assets that pose a risk to society and by turning towards more strategic investments and sustainable asset management, among other specified goals.
- <u>Institutions</u>: An NIP Implementation Office is proposed as an additional branch under Infrastructure Canada to ensure the coordinated implementation of the policy and to provide public and private practitioners, scholars, politicians and decision-makers with a central source of information. Provincial/Territorial Offices and Regional Offices are also suggested to ensure successful implementation. An Infrastructure Bank, such as those established in some States, is proposed to provide a sustained funding source.
- <u>Resources</u>: The proposed policy encourages the use of innovative financing techniques and the Implementation Offices encourage decision-making between an interdisciplinary group of professionals. Modifications to University curricula have been proposed for better training of future graduates entering the domain of public works.

- Knowledge: Further research and development is needed to address the policy issues. The proposed Offices are encouraged to work hand-in-hand with the existing researchers at Infrastructure Canada, the Federation of Canadian Municipalities, Transport Canada, the National Research Council and other infrastructure-related organizations in establishing the infrastructure needs and priority lists. Recommended improvements to the civil engineering curricula include shifting to a focus on infrastructure renovation and upgrading needs and management practices, as opposed to focusing solely on design of new facilities.
- Information and communication systems: A proposed asset management information system is aimed at improving communication between the various parties involved in infrastructure planning, design, construction, maintenance, management, operation and decommissioning.

Finally, the economic, social, environmental and political influences that are driving the need for a National Infrastructure Policy have been reviewed; the related issues are addressed and suitable mitigation strategies are proposed.

Only small steps are being taken in acknowledging the infrastructure crisis. Much more is needed to ensure that the development of Canadian communities is safe, productive and sustainable, and that, as a whole, Canada's international competitiveness remains high. "If we do not maintain our infrastructure, do not upgrade it, we'll continue to have spectacular collapses" (Mirza, 2007). Without a significant shift from the current philosophy of *design, build and forget* to one of *design, build and maintain,* there is no doubt that the recent, frequent infrastructure-related tragedies will continue to be a common trend. The proposed National Infrastructure Policy and related implementation techniques should be considered urgently if Canadians are to move forward to a sustainable and prosperous future.

"The 21st century holds great promise for our nation. But you can't journey to a brighter tomorrow by relying on yesterday's infrastructure" - American Senator Chris Dodd, Chairman of the Senate Committee on Banking, Housing and Urban Affairs, and co-founder of the 2007 National Infrastructure Bank Act.

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Appendix A

Table A.1 Transportation infrastructure-related tragedies: Canada

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
de la Concorde Overpass Collapse, 2006 Laval, Quebec	6/0/5	36	▪ **Design/Construction errors:** insufficient reinforcement and improper placing of rebars ▪ **Deterioration:** degraded concrete in an area with no rebar ▪ **Lack of quality control:** use of low quality concrete ▪ **Poor design from a maintenance point of view:** joints lie above deck support leaving room for ingress of water and de-icing agents at these critical points (Versace, 2007)
Peace River Bridge, 1957 Alcan Highway, British Columbia	0/0/0	14	▪ **Poor construction practices:** inadequate foundation design. North abutment began moving in 1952. ▪ **Inadequate geotechnical investigation:** investigation into the cause of the collapse proved that a landslide of the shale bedrock beneath the bridge led to instability of the foundation ▪ **Lack of experience:** little was known about building on shale rock of the region when the bridge was constructed. It is now known that with time this shale may turn back into mud when exposed to water (APEG BC, 2007)
Second Narrows Bridge, 1930 Vancouver, British Columbia	-	5	▪ **Poor planning and design flaws:** bridge was poorly located – often hit by ships. The last barge to hit took away centre span during high tide, pushing the barge up under the span (Bouton, 2008)

Table A.1 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Under Construction or Rehabilitation Work			
Big Nickel Road Bridge Collapse, at Lorne Street, 2004 Sudbury, Ontario	0/0/0	-	▪ **Deficiencies in the design plans** ▪ **Failure to implement approved plans during restoration** ▪ **Unsafe/Negligent construction practices** (NorthernOntario.org, 2007)
Laval Bridge Collapse, 2000 Laval, Quebec	2/0/1	-	▪ **Unsafe construction practices/inadequate inspections:** concrete beams not properly secured and fell on a passing car (Couvrette, 2006)
Heron Road Bridge Disaster, 1966 Ottawa, Ontario	57/0/9	-	▪ **Inadequate construction practices and use of materials:** lack of diagonal bracing on the wooden support forms and use of green lumber (Laucius, 2006)
Ironworkers Memorial Second Narrows Bridge, 1958 Vancouver, British Columbia	20/0/18	-	▪ **Unsafe construction practices and lack of experience:** the weight of the unfinished bridge span was underestimated and not adequately supported (Bouton, 2008)
Quebec Bridge, 1907 Near Quebec City, Quebec	11/0/75	4	▪ **Design errors:** preliminary calculations not re-checked in final stages – dead load too large ▪ **Lack of experienced supervision:** on-site inspections by experienced supervisor minimal, recent graduate on-site ▪ **Lack of quality control:** some installed members had defects (Ricketts, 2007)

Table A.2 Transportation infrastructure-related tragedies: International

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Pakistan Bridge Collapse, 2007 Karachi, Pakistan	-	One month	▪ Investigation in progress
Minnesota Bridge Collapse, 2007 Minneapolis, Minnesota	79/0/12	40	▪ **Rated "structurally deficient in 1990":** fatigue cracks, high levels of corrosion and other forms of deterioration (rated by the U.S. government). The latest inspection rated the bridge a four out of nine, where nine is perfect and zero requires shutdown (Wald and Chang, 2007) ▪ **Design flaws:** gusset plates were half the size they should have been, sixteen were fractured in the central span (McCarthy, 2008) ▪ **Negligence:** The extra weight of construction added additional load to the bridge, and thus to the inadequately designed gusset plates (McCarthy, 2008)
San Francisco-Oakland Bay Bridge, 2007 San Francisco, California	0/0/1	71	▪ **Careless driving:** gasoline tanker crashed into a guardrail on a curving part of the interchange. A fire spread (2,750°C) causing supporting steel beams to buckle and melting connecting bolts (Wohlsen, 2007)
Guinea bridge Collapse, 2007 Gueckedou, Guinea	- /0/65	-	▪ **Inadequate design:** bridge was unable to support the load of a passing truck full of passengers and merchandise (Thomson Reuters, 2007)
Interstate 80 – Nebraska highway Collapse, 2003 Western Nebraska	0/0/1	36	▪ **Careless driving and possibly inadequate design:** a tractor-trailer slammed into a bridge support and the bridge collapsed (Peterson, 2003)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Toki Messe Sky Bridge, 2003 Bandaijima, Niigata City, Japan	0/0/0	0.42	▪ **Design flaws:** local buckling of a steel frame, concrete inadequately reinforced, flexural failure of the PC floorboards, etc. (Japan Science and Technology Agency, 2008)
Daman Bridge Collapse, 2003 Daman, India	20/0/25 (23 were children)	-	▪ **Lack of maintenance and needed upgrades:** the bridge had been in a state of disrepair for some time (BBC News, 2003)
Interstate 40 – Collapse, 2002 Webbers Falls, Oklahoma	0/0/14	-	▪ **Lack of safety system on the towboat:** towboat's pilot fainted, other crew members were unaware, and the boat's two barges crashed into the bridge pier ▪ **No alert system on bridge:** some deaths could have been prevented if an alert system was set up to warn drivers that the bridge collapsed – some kept driving (Curtis, 2007)
Collapse of the Queen Isabella Causeway, 2001 Cameron County, Texas	13/0/8	47	▪ **Inadequate reinforcement and protection of support columns:** currents drove four barges into a bridge support ▪ **Needed upgrades:** Navigation lights on the causeway were not working (BridgePros, 2008)
Portugal Bridge Collapse, 2001 Lisbon, Portugal	- /0/70	116	▪ **Deferred replacement due to political inaction**: ministers were warned that the 116 year old bridge was unsound and needed to be replaced; bridge pier gave way (BBC News, 2001)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Pedestrian Bridge Collapse, 1999 Sichuan, China	14/0/40	3	▪ **Poor management and construction practices:** company was awarded the contract to construct the bridge after a local party secretary (a childhood friend of the company manager) was bribed. The company may not have been the best option for the job (International Herald Tribune, 2007)
Maccabiah Bridge Tragedy, 1997 Tel Aviv, Israel	60/0/4	-	▪ Bridge was built for the Maccabiah games – a pedestrian bridge for the athletes to enter the opening ceremony ▪ **Project not contracted to an engineering firm:** Contracting companies had never built a bridge before, nor did they have a permit – they specialize in sets for theatre, and stages for indoor and outdoor events ▪ **Sub-standard materials:** bridge was built of rusted pipes held together by wire – considered a “joke” by experts ▪ **Carelessness/criminal negligence:** organizing committee should have never awarded the contract to these inexperienced companies ▪ **Design standards not checked nor met** (Zycher, 1997)
Koror-Babeldaob Bridge, 1996 Palau	4/0/2	19	▪ Primary cause not determined ▪ Speculations involve **construction flaws:** concrete deck inadequate
Walnut Street Bridge, 1996 Harrisburgh, Pensylvania	-	-	▪ **Inadequate foundation design:** failure due to scour caused by flooding (Northwestern University ITI, 2007)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Seongsu Bridge Collapse, 1994 Seoul City, Korea	17/0/32	15	▪ **Deterioration:** highly corroded due to use of de-icing agents ▪ **Deferred maintenance:** low budget for the bridge ▪ **No standards:** no technical standards outlining the maintenance and inspections that would have to be carried out on the bridge ▪ **Poor management:** contract to construct the bridge was awarded without a tender contract system – there may have been better companies suited for the job ▪ **Construction/design flaws:** Poor welding of the I-members (Kunishima, 2007)
Collapse of the Santa Monica Freeway (Interstate Highway 10) and other highways in area, 2004 Northridge, Los Angeles	-	-	▪ **Earthquake:** failure of the support columns ▪ **Inadequate earthquake resistance:** built prior to 1971; subsequently, earthquake resistance design became stricter (Cooper et al, 1994)
Winkley Bridge, 1989 **("The Swinging Bridge")** Heber Springs, Arkansas	18/0/5	77	▪ **Vandalism/Abuse:** Approximately 40 young adults and children on the bridge began to make the suspension bridge "swing" from side to side – leading the bridge cables to give way (Swinging Bridge Village, 2008)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Cyprus Street Viaduct, 1989 Oakland, California	- /0/42	32	▪ **Lack of needed upgrades:** not retrofitted to account for significant changes in the design code for earthquake resistance ▪ **Inadequate earthquake resistance:** braces holding the upper level to the lower level of the double-decker freeway failed. In some parts, the upper deck was not properly connected to the lower deck ▪ **Poor foundation design:** some portions built on fill and not on solid bedrock. The foundation shook side to side, but also up and down during the earthquake (Law, 1999)
San Francisco-Oakland Bay Bridge, 1989 San Francisco, California	- /0/1	53	▪ **Design flaws:** Collapsed during the Loma Prieta earthquake. The U.S. Army Corps of Engineers then found that the bridge had not been designed for the required earthquake magnitude; Richter 8.0 or 7.25 (OBB International Open Forum, 2001)
Hatchie River Bridge Collapse, 1989 Tennessee	0/0/8	53	▪ **Inadequate inspection:** inspections performed without plans, therefore, the extent of scouring was not recorded and monitored (Haestad Methods Inc., 2007) ▪ **Deferred maintenance** due to lack of funding ▪ **Insufficient feasibility studies/planning:** two obstructions in vicinity of bridge and channel constriction caused considerable scouring of the foundation (Kolstad, 1990)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Schoharie Creek Bridge Collapse, 1987 Schoharie Creek, New York	0/0/10	30	▪ **Inadequate foundation design:** not properly designed to resist scour ▪ **Inadequate inspection and maintenance:** extent of scour not detected or dealt with (Storey and Delatte, 2003)
Sunshine Skyway Bridge Collapse, 1985 Tampa Bay, Florida	-/0/35	31	▪ **Inadequate protection of piles and lighting on bridge:** Failure due to ship collision with a central pier during foggy period (Nordheimer, 1985)
Mianus River Bridge, 1983 Greenwich, Conneticut	3/0/3	25	▪ **Structural flaw:** a faulty pin-hangar found in river **Deferred Maintenance:** bridge was severely corroded – corrosion caused displacement of the pin-hangar, displacement caused shearing of pin and fatigue crack ▪ **Inadequate bridge inspections** (Johnson, 1986)
Almö Bridge Collapse, 1980 Tjörn, Sweden	-	-	▪ Failure due to ship collision ▪ **Poor choice of design:** It is still questioned whether another design would have been more suited for that site, where weather conditions and fog caused difficult navigation. A suspension bridge design was considered and would have provided larger clearance, but this choice was disregarded due to cost. ▪ **No alert system on bridge:** some deaths could have been prevented if an alert system was set up to warn drivers that the bridge was collapsing – some kept driving in the fog (Jennings, 1995)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Silver Bridge Collapse, 1967 U.S. Highway 35 bridge connecting Point Pleasant, West Virginia and Kanauga, Ohio	9/0/46	49	▪ **Poor quality control during construction**: one of the eye-bar suspension chains had a small crack ▪ **Lack of maintenance**: crack grew due to stress corrosion and corrosion fatigue ▪ **Inadequate inspection**: no thorough inspection for a 16 year period ▪ **Neglect of needed upgrades**: built in 1928, bridge was not designed for the loads it was carrying in later years ▪ **Poor design from maintenance point of view**: only way to have spotted the crack was to disassemble the eye-bar, but chains were inspected using binoculars (advanced inspection techniques unavailable at that time) (Corrosion Doctors, 2007)
King Street Bridge, 1962 Melbourne, Australia	-	1	▪ **Poor steel selection:** did not respond well to high loading combined with high temperature fluctuations – brittle failure (International Institute of Welding, 2008)
Tacoma Narrows Bridge Collapse, 1940 Tacoma, Washington	0/0/0	0.4	▪ **Poor design/lack of experience:** extreme oscillations of the centre span of this suspension bridge – inadequate stiffness, unable to resist high wind loads, instability during a moderate wind (Washington State DOT, 2008)
Falls View Bridge, 1938 Niagara Falls, Ontario	0/0/0	40	▪ **Inadequate design and stability of foundation:** structural damage due to the weight of large amounts of ice (CBC Digital Archives, 1938)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
While Under Construction or Rehabilitation Work			
Tuo River Bridge, 2007 Fenghuang, Hunan, China	22/46/22	-	▪ Investigations in progress ▪ Collapsed as scaffolding was being removed from the façade
California Bridge Collapse, 2007 Oroville, California	2/0/0	-	▪ Collapse of wood and steel formwork ▪ **Safety Violations:** construction company already had 5 reports of safety violations (Lagos, 2007)
Yekaterinberg Bridge Collapse, 2006 Yekaterinberg, Russia	-	-	▪ Primary cause uncertain at this time
Motorway Bridge Collapse in Almuñécar, 2005 Province of Granada, Spain	3/1/6	-	▪ Steel formwork buckled during concrete pour (The Seaside Gazette, 2005)
Henan Bridge Collapse, 2002 Henan, Central China	2/0/10	-	▪ Collapsed while scaffolding was being removed (The Associated Press, 2002)
East Chicago Bridge Ramp Collapse, 1982 Chicago	17/0/13	-	▪ **Poor construction practices:** concrete pads supporting steel towers under the ramp were not constructed as thick as they should have been (The Associated Press, 1982)
West Gate Bridge Collapse, 1970 Melbouorne, Australia	17/0/35	-	▪ **Design and construction errors:** miscalculations and poor judgment in the design of the steel spans (Flint, 2001)
Cleddau Bridge, 1970 Between Neyland and Pembroke Dock, Wales	5/0/6	-	▪ **Design errors:** steel box girders had design flaws (Flint, 2001)

Table A.2 (Continued)

Event	Injured/ Missing/ Dead	Age (years)	Principal Causes
Sandö Bridge, 1939 Sandö, Sweden	- / - /18	-	▪ **Poor construction practices:** Poor design and timber forms **-** scaffolding collapsed under the weight of the fresh concrete (University of Cambridge, 2008)
During Decommissioning			
Bhagalpur Pedestrian Bridge Collapse, 2006 Bihar, India	18/0/34	150	▪ **Railway industry largely to blame:** train was passing under the bridge as it was partly demolished (two of the three arches were already demolished) ▪ **Demolition practices questioned** (The Associated Press, 2006)

(-) Values are unknown, unavailable in the literature or are not applicable.

Table A.3 Transit infrastructure-related tragedies: Canada

Event	Injured/ Dead	Details and Principal Causes
Toronto Subway Tunnel Accident, 2007 Toronto, Ontario	2/1	▪ A subway car was crushed by pieces of metal used as scaffolding for asbestos removal in the subway tunnel, killing a Toronto Transit Commission maintenance worker operating the car ▪ The subway cars were being used to push a flatbed car carrying heavy metal, when the metal fell onto the car behind it ▪ **Lack of safety standards and precautions** (CBC, 2007)
Toronto Subway Tragedy, 1995 Toronto, Ontario	36/3	▪ "The Worst Subway Tragedy in Canadian History" ▪ Moving train collided with a stationary one ▪ **Inadequate training of personnel:** new driver ran three red lights ▪ **Inadequate disciplinary measures:** drivers should be penalized for running red lights ▪ **Faulty machinery:** a fail-safe trip arm failed, not enabling emergency breaks (Craig, 1995)
Montreal Metro Tragedy, 1971 Montreal, Quebec	35/1	▪ A moving train crashed into a stationary one causing a fire that lasted for 17 hours ▪ $7 million in damage! ▪ **Faulty machinery:** a jammed throttle prevented the brakes from working ▪ **Inadequate fire prevention and ventilation:** since the accident, the city has adopted preventative measures, safety and evacuation procedures, and rapid ventilations instructions (Halton, 1971)

Table A.3 (Continued)

Event	Injured/ Dead	Details and Principal Causes
Victoria Streetcar Accident,1896 Victoria, British Columbia	-/55	▪ "The worst streetcar accident in Canadian history" ▪ **Negligent operations:** a streetcar designed to hold 60 passengers was packed with 142 passengers, causing the underlying wooden bridge - the Pointe Ellice Bridge in Victoria – to collapse (Ingbritson, 2007)

(-) The numbers are unknown, unavailable in the literature, or are not applicable.

Table A.4 Major outbreaks of pathogenic bacteria due to water contamination: Canada

Event	Costs to Society	Principal Causes
North Battleford Cryptosporidium parasite contamination, 2001 North Battleford, Saskatchewan	▪ 6000-7000 cases of illness ▪ \$3.2 million compensation to 700 persons infected with cryptosporidium parasite ▪ \$15 million required to build a new sewage treatment plant, downstream of water intake.	▪ **Design error:** water treatment plant built 2km downstream of the sewage treatment plant, not able to cope with the high level of contamination ▪ **Inadequate treatment:** untreated water with vast amounts of cryptosporidia oocysts released in the waterway from the sewage treatment plant ▪ **Inadequate maintenance:** The treatment plant's "solids contact unit" encounters problems after scheduled maintenance ▪ **Political inaction and negligent operations:** several warnings, starting in 1997 that the treated effluent discharged was not in compliance with the environmental standards of the plant permit. The plant foreman's memos showed the poor condition of the plant before the event occurred: *"This plant is obsolete, potentially hazardous…."* ▪ **Inadequate training of operators and poor management:** There was greater importance on saving money than on dealing with the plant problems (Hnatyshyn Gough Barristers and Solicitors, 2002)

Table A.4 (Continued)

Event	Costs to Society	Principal Causes
Walkerton Tragedy: Outbreak of E-coli bacteria and Campylobacter, 2000 Walketon, Ontario	▪ 1286 cases of illness ▪ 7 deaths ▪ Approximately 2300 cases are associated with the outbreak including people living outside of Walkerton, exposed to the contaminated water on a limited basis (McQuigge, 2000). ▪ 500 chronic cases of diarrhea ▪ 100 permanent kidney failures ▪ Estimated cost of the outbreak: over $155 million	▪ **Poor planning:** Contamination of a shallow well located in close proximity of a cattle farm during a period of heavy rains ▪ **Design error and deficient/obsolete infrastructure:** the water treatment plant could not deal with the levels of turbid water and the water chlorination system plant had not been working properly for some time. ▪ **Negligent operations and unqualified personnel:** water managers were unaware that E-coli was harmful, therefore citizens were not promptly notified about the problems ▪ **Political inaction and inadequate levels of treatment:** The Environment Minister had previously shown concern that chlorination was insufficient (CBC, June 10 2007)
Cryptosporidium parasite water contamination, 1996 Cranbrook, British Columbia	▪ 2000 cases of illness	▪ **Poor planning and inadequate treatment:** Source of livestock feces around the watershed (CBC, 2004)
Cryptosporidium outbreak, 1996 Kelowna, British Columbia	▪ 10,000 – 15,000 cases of illness	▪ **Poor planning and inadequate treatment:** Water contamination with Cryptosporidium parasite from animal feces (CBC, 2004), (Rowe S., 1998)

Table A.4 (Continued)

Event	Costs to Society	Principal Causes
British Columbia, 1980-1998 (cases in Victoria, Valemount, Princeton, Cranbrook, Creston, Revelstoke, Kelowna, Pentincton)	-	▪ **Negligent operations and unqualified personnel:** Ineffective management of watershed infrastructure to minimize contamination of source water (Rowe S., 1998) ▪ Princeton: 88% of the population caught beaver-fever (a beaver in the watermain!)
Cleaning solvent contamination, 1983 Amherst, Nova Scotia	-	▪ **Negligent operations:** Wells contaminated with dry cleaning solvent
Toxoplasmosis outbreak, 1995 Victoria, British Columbia	-	▪ **Negligent operations and inadequate treatment:** Domestic cat or cougar feces contaminated a surface water reservoir (Aramini et al, 1999)

(-) Values are unknown, unavailable in the literature or are not applicable.

Table A.5 Major outbreaks of pathogenic bacteria due to water contamination around the World

Event	Costs to the society	Principal Causes
E. coli outbreak Sweden, 1965	-	▪ (First recorded outbreak of pathogenic *E. coli* due to drinking water contamination) (Rice, 1975)
Jejuni enteritis outbreak Vermont, 1978	▪ Approximately 3000 persons in Bennington, Vermont, developed C. jejuni enteritis	▪ **Inadequate treatment methods:** municipal system with inadequately chlorinated water ▪ **Negligent operations:** the water system was contaminated with water from an unfiltered source (U.S. Food and Drug Administration, 1991)
Several epidemics outbreaks Finland, 1980-1992	▪ 7700 cases of illness ▪ 24 reported waterborne outbreaks	▪ **Inadequate water treatment** ▪ Main cause - contaminated groundwater rather than surface water ▪ Generally, Finnish groundwater is distributed in the water supply network without any treatment or only with alkalization (water source are very clean) (Lahti et al, 1995)
Cryptosporidium outbreak, 1987 Carrollton, Georgia	▪ 13,000 people affected	▪ **Poor planning:** Source of livestock feces around the watershed ▪ **Inadequate treatment methods:** "Current standards for the treatment of public water supplies may not prevent the contamination of drinking water by cryptosporidium" (Hayes et al, 1989)

Table A.5 (Continued)

Event	Costs to the society	Principal Causes
E. coli outbreak, 1989-1990 Missouri	▪ 243 cases of illness ▪ 4 deaths	▪ **Inadequate water treatment and severely deteriorated water pipes:** No water chlorination (Swerdlow et al, 1992)
Cryptosporidium outbreak, 1993 Milwaukee, Wisconsin	▪ 403,000 cases of illness ▪ Over 100 deaths ▪ 880,000 affected (served by the affected treatment plant)	▪ **Negligent operations and inadequate treatment:** One of the two city water purification plants contaminated with sewage, and the plant operated under abnormal turbidity levels for a little over two weeks (Blair, 1995)
E. coli and Campylobacter outbreak, March 1995 Fife, Scotland	▪ 633 cases of illness ▪ 711 reported gastrointestinal symptoms	▪ **Negligent operations and inadequate treatment:** Water supply contaminated with sewage discharge (Jones et al, 1996)
Outbreak of Cryptosporidium and Giardia, 1998 Sydney, Australia	▪ 3 million affected ▪ Tens of millions of dollars spent on public inquiry and liability settlements	▪ **Negligent operations and inadequate treatment:** Cryptosporidium and Giardia pathogens were found in the water supply system (Leiss, 2007)
E. coli and Campylobacter outbreak, 1999 New York State (Washington County Fair)	▪ 921 persons reported diarrhea after attending the Washington County Fair ▪ 116 cases of illness	▪ **Negligent operations and inadequate treatment:** Residents consumed water from an unchlorinated well (Bopp, 2003)
United States, 1976-1998	▪ 534,000 cases	▪ **Divers Cases:** waterborne diseases due to drinking water system contamination (data compiled by Schneider, 2007)

Table A.6 The World's deadliest rail accidents (CBS, 2007), (Francis, 2007)

Date	Location	Description	Fatalities
22 May 1915	Gretna, Scotland	Passenger train collides with troop train	227
12 December 1917	Modane, France	Troop train derailment	543
16 January 1944	Leon, Spain	Train wreck in tunnel	500
2 March 1944	Salerno, Italy	Train stalls in tunnel, suffocating passengers	521
22 October 1949	Dwar, Poland	Express train derailment	200
3 April 1955	Guadaljara, Mexico	Train plunges into canyon	300
29 September 1957	Montgomery, West Pakistan	Express train collides with oil train	250
1 February 1970	Buenos Aires, Argentina	Express train collides with commuter train	236
2 October 1972	Saltillo, Mexico	Derailment causing conflagration	208
6 June 1981	Bihar, India	Flash floods and a cyclone cause a railway bridge collapse and train derailment	800
3 June 1989	Ufa, USSR	Explosion of liquefied gas pipeline engulfs two trains	575
4 January 1990	Sindh Province, Pakistan	Overcrowded passenger train collides with freight train	210
22 September 1994	Tolunda, Angola	Faulty brakes cause a train to plunge into a ravine	300
20 August 1995	Firozabad, India	Passenger train collides with a train stalled by a cow	358
2 August 1999	Gauhati, India	Head-on collision of express trains	285
20 February 2002	Cairo, Egypt	Train burst into flames and traveled 2.5 miles before stopping	360
18 February 2004	Neyshabur, Iran	Runaway cars carrying fuel and industrial chemicals derail and explode	200
25 April 2005	Amagasaki, Japan	Passenger train derails and collides with apartment building	440

Table A.7 Summary of rail accidents in Canada since 1991 (Transportation Safety Board of Canada, 2007), (Public Safety Canada, 2005), (Fancis, 2007)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
31 January 1991	Ottawa, ON	VIA	Axle failure due to in-service stresses from shelled wheels	0/0	Locomotive, one coach, 1000 ft (304.8m) of track	None
13 August 1993	Sudbury, ON	CN	Wheel climb derailment due to lack of side bearing clearance and worn truck components. Hydrogen sulfide leak from incorrectly applied and deteriorated mainway nozzle gasket	0/0	Two cars, 1000 ft (304.8m) of track, one switch	Leaked hydrogen sulfide
3 December 1993	Calgary, AB	CN, CP	Inadequate crew vigilance in the yard	0/3	Two locomotives, 200 ft (61m) of track	None
18 January 1994	Latornell, AB	CN	Runaway Train due to inoperative dynamic braking system and build-up of snow and ice on brake shoes	0/0	None	None
23 January 1994	Longlac, ON	CN	Derailment due to closure rail fracture initiated by vertical split head defect	0/0	26 cars	None
24 January 1994	Calgary, AB	CN	Poorly operating hand brake, crew ignored operating procedure	0/2	Warehouse	None
27 January 1994	Montreal, QC	CN	Tank shell fractured from impact forces	0/0	Tank car	Leaked 1,125 litres of gasoline
30 January 1994	Westree, ON	CN	Derailment due to rail head fracture initiated by vertical head split defect	0/0	23 cars, 1000 ft (304.8m) of track	Spilled 79,000 kg of vinyl acetate, leaked methanol

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
26 February 1994	Stavert, ON	Algoma Central Railway	Derailment due to rail joint splice bar fracture	0/0	20 cars, 300 ft (91.4m) of track, electrical power pole	None
6 March 1994	Markham, ON	CN	Derailment due to rail head fracture resulting from vertical split head defect	0/0	21 cars, 1700 ft (518.2m)of track, railway bridge	None
30 March 1994	Lethbridge, AB	CP	Dump truck hit the train at a level crossing	1/2	One car, dump truck, concrete block building	Diesel fuel leaked from dump truck
25 April 1994	Orient Bay, ON	CN	Derailment due to roadbed washout	0/3	15 cars, 2 locomotives, 500 ft (152.4m) of track	Leaked 1,500 gallons of diesel fuel
7 June 1994	Saint-Georges, QC	CN	Collision due to overly high operating speeds in a yard	0/3	2 trains	None
22 September 1994	Fort Langley, BC	CN	Collision with a garbage truck due to inadequate warning/barrier systems	2/0	Garbage truck	None
23 September 1994	Louiseville, QC	CP	Collision of the train with a motor home	2/1	Motor home, locomotive	None
17 October 1994	Lethbridge, AB	CP	Derailment due to rail fracture resulting from fatigue cracks	0/0	Five cars, 300 ft (91.4m) of track	Leaked 230,700 litres of methanol
18 October 1994	Regina, SK	CP	Unsafe operating practices	0/0	Four cars, 150 ft (45.7m) of track	Leaked 4000 litres of diesel fuel

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
19 October 1994	Lac Edouard, QC	CN	Derailment due to low operating speed	0/0	12 cars	None
28 October 1994	Etobicoke, ON	CN	Collision due to overly high operating speed	0/0	3 cars	None
4 November 1994	Riviere-Beaudette, QC	VIA	Collision with a tractor-trailer that was abandoned on the tracks by the driver as he saw warning devices activate as he entered the railway crossing	0/4	5 cars, tractor-trailer	None
20 November 1994	Brighton, ON	VIA	Train hit a piece of rail intentionally placed on the tracks	0/46	8 cars	None
14 December 1994	Causapscal, QC	CN	Failure of computer-assisted train control system to deactivate track blocked by a tractor-trailer	0/0	9 cars, 2 locomotives, 800 ft (243.8m) of track, bridge, tractor-trailer	None
20 January 1995	Procter, BC	CP	Derailment after striking fallen rock	3/1	3 locomotives, 2 cars	Lead sulphide, 28,000 litres of diesel fuel
21 January 1995	Gouin, QC	CN	Derailment due to deteriorated ties	0/0	26 cars, 2500 ft (762m) of track, railway bridge	Leaked 230,000 litres of sulphuric acid
29 January 1995	Netherby, ON	CN	Collision due to excessive speed	0/2	7 cars	None
16 February 1995	London, ON	CN	Collision with a stationary freight train due to operator falling asleep and missing important restrictive signals	0/2	8 cars, 2 locomotives, 400 ft (122m) of track	None
23 February 1995	Saint-Francois, QC	VIA	Car derailment due to broken switch	0/0	2 cars, 5460 ft (1664m) of track	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
31 March 1995	Toronto, ON	CN	Leak caused by fatigue crack	0/0	None	Leaked 23 litres of toluene
20 April 1995	Brockville, ON	CN	Two pedestrian fatalities at a level crossing	2/0	None	None
22 April 1995	Blue River, BC	VIA	Locomotive wheel fracture due to internal overstress cracking	0/12	5 cars, 5700 ft (1737.4m) of track	None
18 May 1995	Toronto, ON	CP	Collision due to unsafe speed and alcohol-related impairment	0/2	2 cars, 1 locomotive, 100 ft (30.5m) of track, 100 ft (30.5m) of fencing	None
6 June 1995	Saint-Leonard, QC	CN	Collision with a tractor-trailer	1/0	Tractor-trailer	None
21 June 1995	La Doré, QC	CN	Derailment due to washout of subgrade from breached beaver dam	0/0	8 cars, 4 locomotives, 700 ft (213.4m) of track	Leaked 31,800 litres of diesel fuel
24 June 1995	Lennoxville, QC	Canadian American Railroad Company	Wheel climb derailment due to track irregularities	0/0	7 cars, 750 ft (228.6m) of track	None
20 August 1995	Savona, BC	CP	Collision due to a missed signal	0/2	10 cars, 3 locomotives	None
1 October 1995	Greely, BC	CP	Collision due to a missed signal and operator fatigue	0/4	2 locomotives	None
10 March 1996	Dix, QC	CN	Derailment due to missing track components	0/0	27 cars, railway bridge	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
11 March 1996	River Glade, NB	CN	Derailment due to rail head and web fracture	0/0	22 cars, 1400 ft (426.7m) of track	Leaked 455 litres of gasoline, butane
21 March 1996	Oshawa, ON	VIA	Derailment due to frozen disc brakes	0/0	1 car, 1500 ft (457.2m) of track	None
31 March 1996	North Bay, ON	CN	Derailment due to damaged switch caused by a highway vehicle collision	0/10	3 cars, 350 ft (106.7m) of track	None
14 June 1996	Nicholson, BC	CP	Derailment due to a track buckling and incomplete tie renewal work	0/0	11 cars, 950 ft (289.6m) of track	Spilled 1,100 tons of coal
12 July 1996	Tecumseh, ON	VIA	Fatal striking of a pedestrian due to inadequate horn warning	1/0	None	None
14 July 1996	Mai, QC	Quebec North Shore and Labrador Railway	Collision due to an ignored signal	0/1	3 cars, 1 locomotive	None
12 August 1996	Edson, AB	CN	Collision of a freight train and runaway cars due to insufficient brake shoe force	3/0	23 cars, 3 locomotives	None
29 August 1996	Dalhousie Mills, QC	St Lawrence & Hudson Railway	Wheel climb derailment due to car body roll and truck hunting	0/0	3 cars	Leaked 1,900 litres of hydrogen peroxide
30 January 1997	Brockville, ON	CN	Track side frame failure due to a casting defect, non-standard weld and substandard fracture toughness	0/0	None	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
26 March 1997	Conrad, BC	CN	Derailment due to a depression caused by unsustainably high pore pressure in the track subgrade	2/0	14 cars, 2 locomotives, 1200 ft (365.8m) of track	Spilled sulphur pellets
7 April 1997	Pointe au Baril, ON	CP	Derailment due to subgrade failure caused by high pore pressure in loose sand	0/3	14 cars, 4 locomotives	Leaked 45,000 litres of diesel fuel, 30 tonnes of lead sulphide
6 May 1997	Coteau-du-Lac, QC	CN	Derailment due to depressed subgrade	0/2	12 cars, 2 locomotives, 270 ft (219.5m) of track	Leaked, 12,000 litres of diesel fuel
3 September 1997	Biggar, SK	VIA	Derailment due to fracture of lead axle and inadequate employee training	1/79	13 cars, 2 locomotives, 600 ft (182.9m) of track	None
19 November 1997	Toronto, ON	GO Transit	Collision and derailment due to train reversal without critical information	0/56	12 cars, 1 locomotive, 500 ft (152.4m) of track	None
24 November 1997	Carrier, QC	CN	Splitting of a tank car due to fabrication with a gap and missing but weld	0/0	1 car	Spilled 51,326 litres of sulphuric acid
2 December 1997	Field, BC	CP	Derailment of 66 cars due to inappropriate train handling decisions	0/0	64 cars, 2500 ft (762m) of track	None
1 March 1998	Lyn, ON	CN	Derailment due to inadequate maintenance and inspection of a defective switch point	0/0	None	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
31 May 1998	Creston, BC	CP	Derailment due to saturation and failure of subgrade fill	0/0	8 cars, 3 locomotives, 150 ft (45.7m) of track	Leaked 21,000 litres of diesel fuel and 90 cubic metres of silver/lead concentrate
17 June 1998	Campbellville, ON	St Lawrence & Hudson Railway	Collision due to operating errors	0/0	None	Leaked 2,000 gallons of diesel fuel oil
31 July 1998	Mont-Joli, QC	VIA	Collision with a runaway five-platform container car due to employee noncompliance with procedures	0/3	1 car, 1 locomotive	None
26 November 1998	Concord, ON	CN	Yard derailment due to rail breaks and under-inspected tracks	0/0	1 car	Minor anhydrous ammonia leak
31 January 1999	Jasper, AB	CN	Collision due to extreme blowing snow conditions rendering air brakes ineffective	0/1	3 cars, 5 locomotives, 520 ft (158.5m) of track	None
6 February 1999	Neswabin, ON	CN	Derailment due to burnt-off axle journal	0/0	20 cars, 500 ft (152.4m) of track, hot box detector	Leaked benzene, dicyclopentadieneand liquefied petroleum gas
13 April 1999	Begin, QC	CN	Derailment due to soft subgrade	0/0	11 cars, 750 ft (228.6m) of track	Leaked 230 litres of gasoline

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
23 April 1999	Thamesville, ON	VIA	Derailment due to a reversed switch	2/77	7 cars, 1 locomotive, 150m of track	Ammonium nitrate
5 June 1999	Bellamy, ON	VIA	Collision with a motor vehicle	2/0	Motor vehicle	None
26 June 1999	Keewatin, ON	CP	Derailment due to subgrade failure	0/0	None	None
14 July 1999	Hornepayne, ON	VIA	Collision with tractor-trailer	0/8	8 cars, 3 locomotives	Leaked 11,000 litres of diesel fuel
6 August 1999	Windsor, ON	VIA	Collision with two wheelchair-bound pedestrians due to poor condition of the crossing	0/2	Wheelchair	None
15 August 1999	Messiter, BC	CN	Derailment due to wheel fracture caused by shelling	0/0	None	Spilled 5000 tons of mixed grains
27 August 1999	Cornwall, ON	CN	Derailment in a yard due to insufficient hand brake application, ignorance of company procedures	0/0	1 car	Leaked 5000 gallons of Class 3 combustible liquid
23 September 1999	Britt, ON	CN	Derailment due to deficient track conditions	0/4	18 cars	127,000 lbs (57,606 kg) of liquefied petroleum gas and 158,000 lbs (71,667.6 kg)of anhydrous ammonia consumed by fire

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
9 October 1999	Bedford, NS	CN	Derailment due to damaged rail caused by shelly damage	0/0	2 cars, 800 ft (243.8m) of track	None
1 November 1999	Poplar Point, MB	CP	Derailment of double-stacked cars due to high cross-winds	0/0	3 cars, 3 locomotives	None
9 November 1999	Limehouse, ON	VIA	Collision with a dump truck	1/17	3 cars, 1 locomotive, dump truck	Spilled fuel oil
23 November 1999	Bowmanville, ON	CN, VIA	Collision with an abandoned tractor-trailer	0/11	12 cars, 3 locomotives, tractor-trailer, 700 ft (213.4m) of track	Leaked 11,350 litres of diesel fuel
30 December 1999	Mont-Saint-Hilaire, QC	CN	Derailment due to rail head separation causing collision of two freight trains	2/0	61 cars, 2 locomotives	Spilled 2.7 million litres of hydrocarbons that caught fire
30 January 2000	Miramichi, NB	VIA	Collision due to diversion from the main track caused by a reversed crossover switch	0/43	21 cars, 2 locomotives	None
10 March 2000	Brossard, QC	CN	Derailment – the weight of the train caused the track gauges to exceed standards. The wheels of one of the cars dropped between the rails	0/0	5 cars, 170 ft (51.8m) of track	None
14 March 2000	Temagami, ON	Ontario Northland Railway	Derailment due to deteriorated track conditions	0/0	23 cars	Spilled 386,000 litres of sulphuric acid

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
22 May 2000	Cressman, QC	CN	Derailment due to vertical split head	0/0	3 cars, 400 ft (121.9m) of track, railway bridge	None
20 June 2000	Chalk River, ON	Ottawa Valley Railway	Derailment due to defective ties unable to withstand lateral loading	0/0	13 cars, 600 ft (182.9m) of track	None
9 July 2000	Rockwood, ON	VIA	Collision with track machines due to diversion onto a siding caused by a reversed switch	0/14	2 cars, 1 locomotive, 400 ft (121.9m) of track, 4 track machines	Released 200 litres of petroleum products
30 August 2000	La Tuque, QC	VIA	Collision with a dump truck at a crossing in non-compliance with safety standards	1/1	3 cars, 1 locomotive, 515 m of track, dump truck	Spilled and combusted diesel fuel
28 September 2000	Limehouse, ON	VIA	Collision with a motor vehicle at a construction site	3/0	Motor vehicle	None
30 November 2000	Winnipeg, MB	CP	Derailment due to subsurface fatigue cracking of a wheel	0/0	Cars, track	None
9 December 2000	Blue Bell, NB	CN	Derailment due to failure of a thermite weld	0/0	7 cars, 660 m of track	Released white asbestos
11 December 2000	Shabaqua, ON	CN	Derailment due to rail failure following emergency brake application	0/0	17 cars	Spilled 100,000 litres of methanol
12 December 2000	Lone Rock, SK	CP	Derailment due to brittle rail fracture	0/0	12 cars, 600 ft (182.9m) of track	Spilled 84,000 litres of liquid kerosene and 150,000 litres of liquid asphalt

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
19 December 2000	Imperial Mills, AB	Athabasca Northern Railway	Collision with two trucks due to driver expectation of unoccupied crossing	1/0	2 cars, 2 trucks	None
8 January 2001	Bowker, ON	CP	Derailment due to exceedance of the lateral restraining capacity of the track	0/0	59 cars, 3500 ft (1066.8m) of track	None
16 January 2001	Mallorytown, ON	CN	Wheel lift derailment due to high buff forces	0/0	5 cars, 2600 ft (792.5m) of track	None
2 February 2001	Red Deer, AB	CP	Derailment due to wide gauge	1/34	2 cars	Leaked 71.74 tonnes of anhydrous ammonia
15 February 2001	Trudel, QC	CN	Derailment due to an axle fatigue fracture	0/0	25 cars, 800 m of track	None
12 March 2001	Bonfield, ON	Ottawa Valley Railway	Derailment due to a vertical split head fracture	0/0	13 cars, 500 ft (152.4 m) of track	None
12 April 2001	Stewiacke, NS	VIA	Derailment due to a vandalized switch	0/22	9 cars, farm supply building	None
9 May 2001	Burlington, ON	CN	Collision with a pedestrian	1/0	None	None
1 October 2001	Kemnay, MB	CP	Derailment due to track cross-level and alignment deviations	0/0	9 cars	None
6 October 2001	Drummond, NB	CN	Derailment due to collision with an automobile that stalled on the rail crossing (the occupants ran for safety)	0/0	9 cars, 1000 ft (304.8 m) of track	Released butane
15 February 2002	Dartmouth, NS	CN	Derailment due to deteriorated ties	0/0	5 cars, 300 ft (91.4 m) of track	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
22 February 2002	Port Hope, ON	CP	Collision due to inattention to signals	0/0	2 cars	None
3 March 2002	Carmangay, AB	CP	Derailment due to surface defects that developed into transverse defects	0/0	8 cars, 500 ft (152.4 m) of track	Spilled 90 tonnes of ammonium nitrate and 10 tonnes of potash
18 March 2002	Eric, QC	Quebec North Shore and Labrador Railway	Derailment due to sudden rail break	0/0	40 cars, 300 m of track	None
26 April 2002	Winnipeg, MB	CN	Derailment due to wheel lift, train's high speed did not meet requirements at crossover	0/0	8 cars, 300 ft (91.4 m) of track, underpass (type of damage not specified)	None
2 May 2002	Firdale, MB	CN	Derailment resulting from collision with a tractor-trailer	0/0	17 cars, 2 locomotives, 700 ft (213.4 m) of track, tractor-trailer	Spilled and combusted 548,000 pounds (248,569 kg) of a benzene-dicyclopentadiene mixture and 162,000 pounds (73,482 kg) of hexene
13 May 2002	Kingston, ON	VIA	Collision with a low-clearance, immobilized tractor-trailer	0/1	Tractor-trailer	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
3 July 2002	L'Assomption, QC	CN	Derailment due to a track buckle caused by heat stresses	0/0	14 cars, 1830 ft (557.8 m) of track	None
8 July 2002	Camrose, AB	CN	Derailment due to ejection of a lightweight hopper car caused by transformed lateral forces	0/0	13 cars, 2 locomotives, 860 ft of track	None
23 July 2002	Carstairs, AB	CP	Derailment due to track buckling caused by high compressive stresses	0/0	14 cars, 440 ft (262 m) of track	Leaked 200 litres of ethylene glycol
13 August 2002	Milford, NS	CN	Derailment due to track buckling caused by an excessive ballast condition from frequent surfacing and thermal stresses	0/0	7 cars, 2.85 miles (4.6 km) of track	None
24 October 2002	Hibbard, QC	CN	Derailment due to a longitudinal rail fracture	0/0	6 cars, 275 m of track	None
4 December 2002	Bullshead, AB	CP	Derailment due to sudden break	0/0	10 cars, 440 ft (134.1 m) of track	Spilled molten sulfur that caught fire
21 February 2003	Melrose, ON	CP	Derailment due to a burnt-off axle journal and subsequent collision with another train	0/2	21 cars, 1 locomotive, 635 ft (193.5 m) of track	Spilled and burned 407,000 kilograms of liquefied petroleum gas and 3000 gallons of diesel fuel
27 March 2003	Sherbrooke, QC	St Lawrence & Atlantic Railroad	Derailment due to rail failure under heavy axles	0/0	11 cars, 150 m of track	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
12 May 2003	Manseau, QC	CN	Derailment due to fatigue failure of the platform of a container car and subsequent falling on, and fracture of, the track	0/0	1300 ft (396.2 m) of track	None
14 May 2003	McBride, BC	CN	Derailment due to guard rail installation not meeting standards	2/0	5 cars, 2 locomotives, the entire bridge due to resulting fire	None
21 May 2003	Gamebridge, ON	CN	Derailment due to track surface defects	0/3	49 cars, 1700 ft (518.2 m) of track	Spilled 250 tons (250,000 kg) of sulphuric acid
30 July 2003	Villeroy, QC	CN	Derailment due to track buckle where maintenance was underway	0/0	32 intermodal platforms, 2200 ft (670.6 m) of track	None
19 October 2003	Carlstadt, ON	CP	Derailment due to burnt-off roller bearing and axle journal	0/0	2 cars, 10 miles of track	None
14 January 2004	Whitby, ON	CP	Derailment due to brittle downward fracture of the rail	2/0	200 ft (61 m) of track, automobile, bridge	None
7 February 2004	Montmagny, QC	CN	Derailment due to car body oscillation, which may result with a combination of high speeds and an empty car weight, for cars of certain lengths	0/0	27 cars, 1500 ft (457.2 m) of track, bridge, 2 crossings	None
17 February 2004	Winnipeg, MB	CN	Derailment due to reversed switch caused by frost buildup	0/0	17 cars, 1600 ft (487.7 m) of track	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
17 March 2004	Linton, QC	CN	Derailment due to vertical split head caused by fatigue failure	0/0	22 cars, 140 m (42.7 m) of track	None
18 April 2004	Linacy, NS	Cape Breton and Central Nova Scotia Railway	Derailment due to track irregularities	0/0	13 cars, 1100 ft (335.3 m) of track	None
28 June 2004	Munster, ON	VIA	Collision with a dump truck	1/0	Dump truck	None
8 August 2004	Estevan, SK	CP	Derailment due to a rail roll-over	0/0	1 car, 450 ft (137.2 m) of track	Released anhydrous ammonia
17 August 2004	Saint-Henri-de-Levis, QC	CN	Derailment possibly due to differential settlement	0/0	18 cars, 250 m of track	Spilled 200,000 litres of gasoline and diesel fuel
6 October 2004	Castleford, ON	CP	Collision with a private vehicle	1/0	Private vehicle	None
12 November 2004	Levis, QC	CN	Derailment due to wheel failure caused by crack propagation	0/0	10 cars, 500 m of track, 2 switches	None
31 January 2005	MacKay, AB	VIA	Collision with a logging truck	0/3	9 cars, 1 locomotive, 245 m of track	Spilled 6500 litres of diesel fuel
17 February 2005	Brockville, ON	CN	Collision with two pedestrians	1/1	None	None

Table A.7 (Continued)

Date	Nearest Location	Operator	Probable Cause	Fatalities/ Injuries	Damage	Environmental Impacts
23 February 2005	Saint-Cyrille, QC	CN	Derailment due to wheel failure caused by crack propagation	0/0	29 cars, 4600 ft (1,402.1 m) of track, mill	Combusted propane tank car
2 May 2005	Maxville, ON	Ottawa Central Railway	Collision due to undesired release of air brakes	0/0	2 cars	Spilled 98,000 litres of denatured alcohol
3 August 2005	Wabamun, AB	CN	Derailment	0/0	43 cars	Leaked 700,000 litres of bunker C fuel and pole-treating oil
5 August 2005	Garibaldi, BC	CN	Derailment due to incorrect train setup and operation	0/0	9 cars	Leaked 40,000 litres of caustic soda

Appendix B

Table B.1 Canadian infrastructure surveys – 1985 - 2007

Organization Group	Details about Respondents and Response Rate	Main Objectives	Year
Federation of Canadian Municipalities (FCM)	▪ 71 municipalities responded ▪ Approximately 300 were sent the survey ▪ 100% response rate from 8 cities with populations greater than 400,000 ▪ 50% of population represented for municipalities in the 100,000 to 400,000 population demographic ▪ 20% represented for the 10,000 to 100,000 group ▪ Only 24 of 104 smaller-rural communities responded (survey findings were not representative of these smaller communities)	▪ To establish an inventory of the state of infrastructure in Canada ▪ Evaluate the trends in government spending on infrastructure in the past 15 years ▪ Determine the sources of funds for infrastructure across Canada ▪ Determine the needs - financial and changes in common practices – to bring the infrastructure to acceptable levels (FCM, 1985)	1985
FCM	▪ A "green card" questionnaire was distributed to delegates at the 1992 Annual Conference in Montreal	▪ To update the findings of the 1985 survey	1992
FCM and McGill	▪ 36% response rate: 167 responded of the 589 municipalities that were sent the survey ▪ 55% of national population represented (Al-Haroun and Siddiqui, 1995)	▪ Update existing information on the state of infrastructure in Canada ▪ Draw comparisons with the state of infrastructure in 1985, as established from the previous FCM survey ▪ Evaluate the impact of the Federal $6 billion dollar infrastructure program	1996

Table B.1 (Continued)

Organization Group	Details about Respondents and Response Rate	Main Objectives	Year
Technology Roadmap (TRM)	(The study did not constitute and new survey)	▪ To update the deficit estimate, based on data from past surveys	2003
FCM and McGill	▪ 51% response rate: 85 of 166 full and partial responses were received ▪ 46% of national population represented	▪ Evaluate the total municipal infrastructure deficit and the deficits for the main infrastructure categories and sub-categories ▪ Evaluate the influence of constraints such as population growth and environmental regulations on the growth of the deficit ▪ Determine financial, managerial, technical and other future needs of the municipalities in dealing with infrastructure ▪ Evaluate the impact of past surveys	2007

Table B.2 Other Canadian infrastructure surveys – 2004 – 2006

Organization Group *Survey*	**Details about Respondents and Response Rate**	**Main Objectives**	**Year**
National Research Council (NRC) – Institute for Research in Construction (IRC) *Survey on Municipal Infrastructure Assets*	▪ 13% response rate: 67 out of 545 municipalities/towns/districts in Canada with population greater than 5,000	▪ Obtain information on actual and needed investments for infrastructure maintenance and determine how maintenance priorities are established ▪ Determine which asset management practices are in use ▪ Determine the state of Canada's municipal infrastructure (Vanier and Rahman, 2004)	2004
IPSOS REID marketing research and Municipal World municipal magazine *IPSOS REID/Municipal World Survey*	▪ The general public: 1,173 respondents from different provinces	▪ To examine how Canadians rate the quality of various elements of public infrastructure ▪ To determine how public views infrastructure-related issues and infrastructure among government priorities (Gunther et al, 2007)	2006

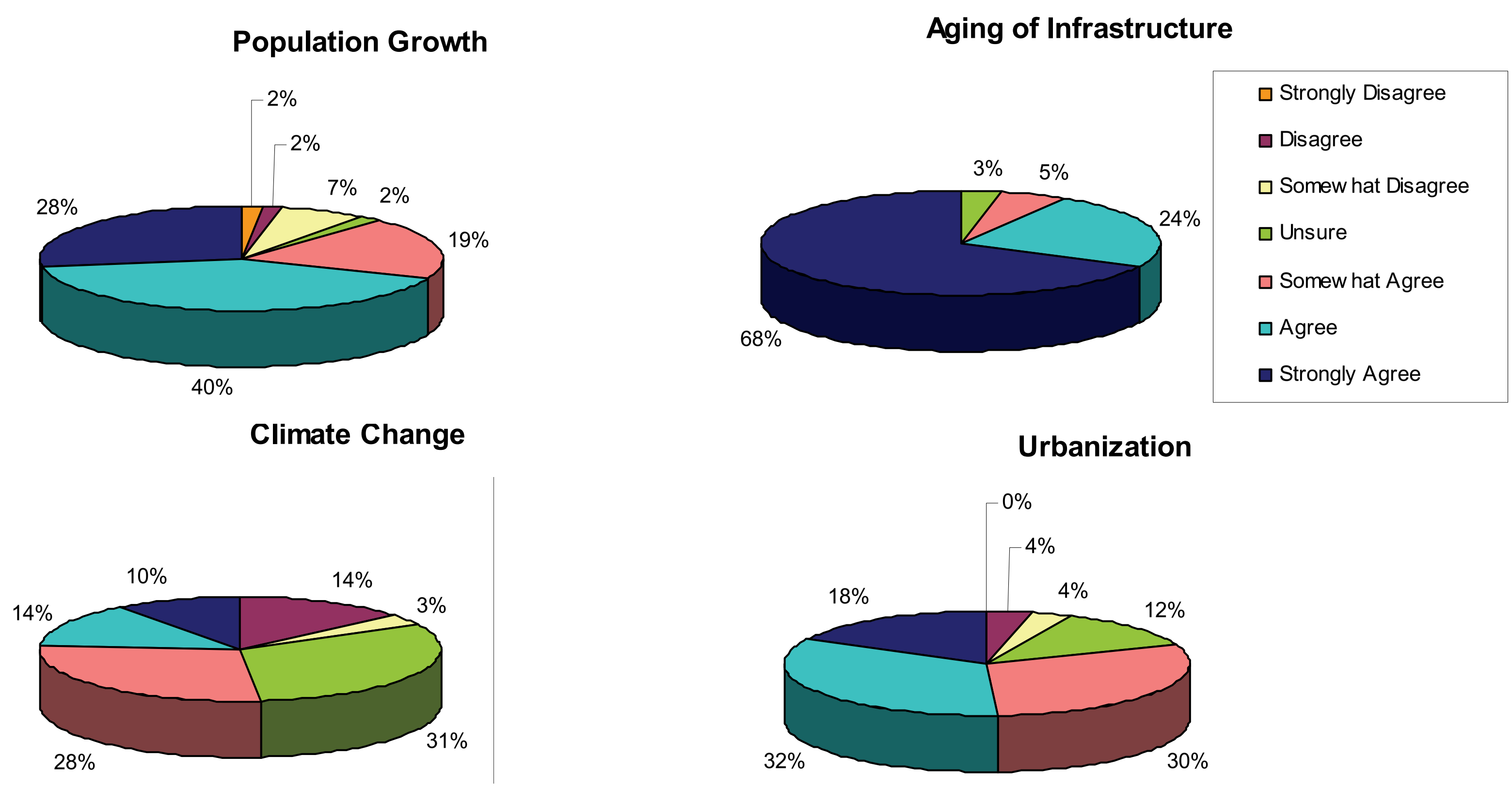


Figure B.1 Factors influencing the municipal infrastructure deficit.

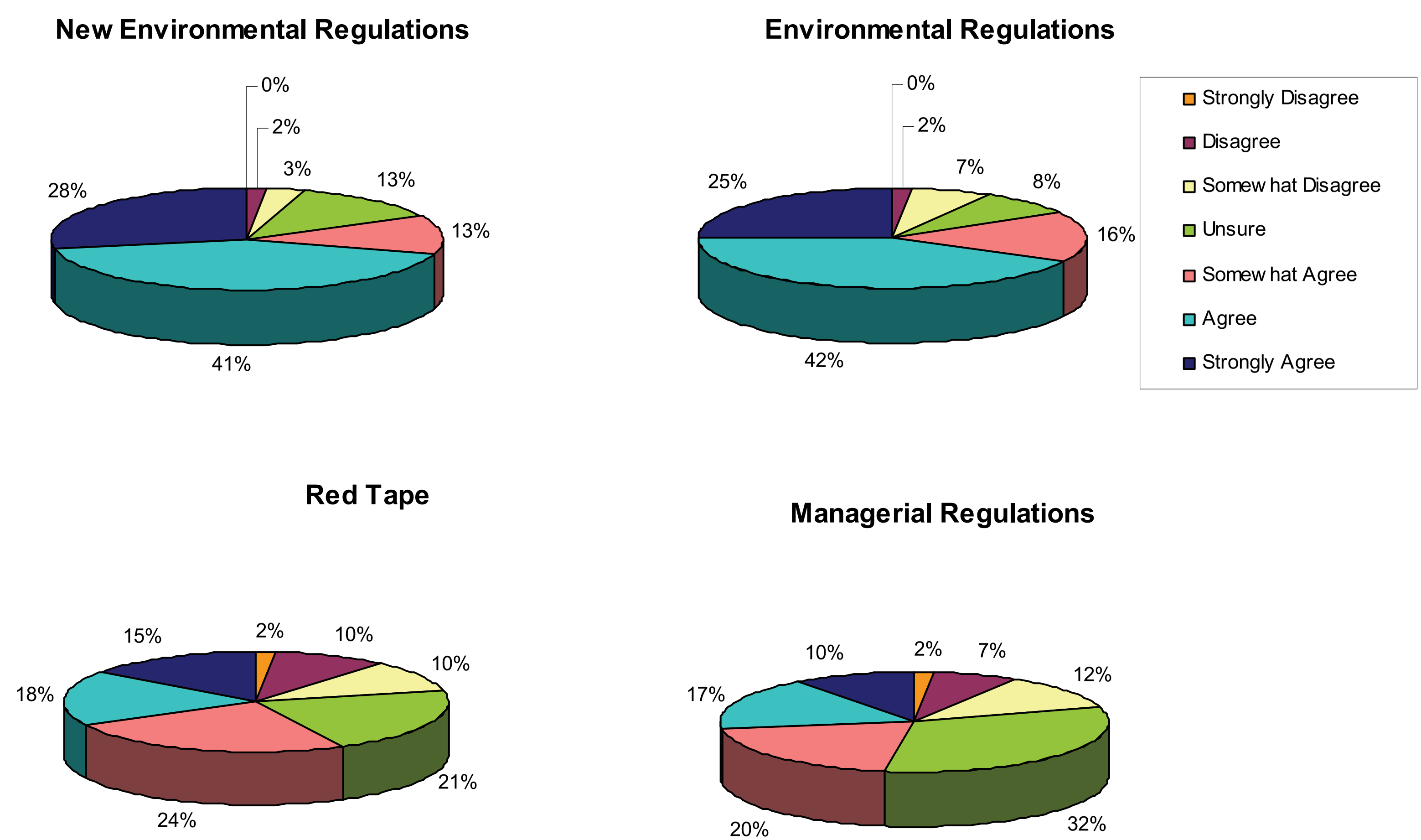
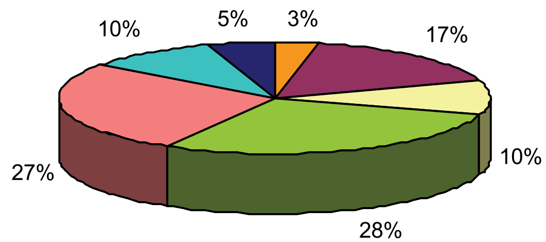


Figure B.1 (Continued)

Lack of Technical and Managerial Expertise



Lack of Training Opportunities

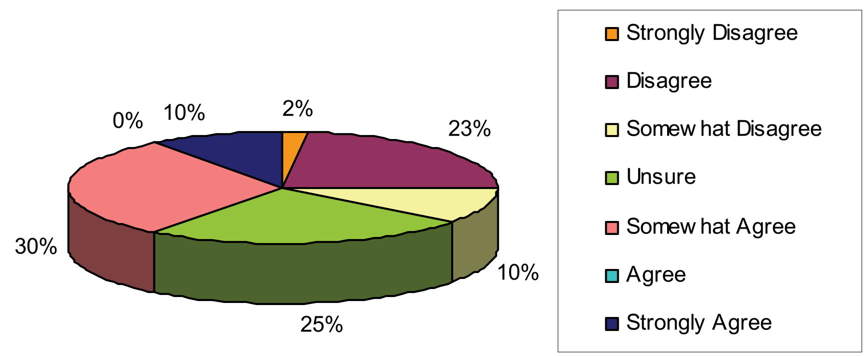


Figure B.1 (Continued)

Appendix C

2008 Municipal Infrastructure Public Questionnaire

1) What is your occupation (if you are a student please specify in what field):

The occupations of respondents include:

Administrative Assistant – Pharmaceuticals	Facilities Specialist, Corporate Facilities Department	Nurse	Student - Biology
Assistant Vice President Client Services	Graduate Student – Civil Engineer	Nurse - Manager	Student - Building Engineering
Career Counselor	Homemaker	Painter	Student - Business
Chartered Accountant	Human Resources	Photographer	Student - Civil Engineering
Civil Engineer	Information Technology	Process Engineer	Student - Finance
Civil Engineering Technologist	IT Specification Analyst	Program Coordinator	Student - Law
Communication – Advertising	Intervenant	Retired	Student - Management
Day Care Educator	Jr. Civil Engineer	Regional Rep. for a documentation application – Pharmaceuticals	Student-Marketing
Document specialist	Manager Financial Results – Bell	RBC Branch Operations	Student - Sociology
Educator	Marketing and Research Associate	Scientist (Jr. Eng.) – Pharmaceuticals	Teacher
Electrician	Marketing Researcher	Social Worker	Technician
Electrician	Marketing	Structural Engineer	Theology
		Student - Accountant	Writer

2) Age Group: (please mark an "x" beside the applicable group)

a) <20
b) 20 – 25
c) 26 – 30
d) 31 – 40
e) 41 – 50
f) 51 – 60
g) >60

Responses:

Age Group	No. of Responses
<20	0
20 – 25	25
26 – 30	10
31 – 40	7
41 – 50	10
51 – 60	9
>60	3
Total	**64**

3) Municipality and Borough of Residence (e.g. Montreal, Rosemont):

Respondents are from the following municipalities:

Ahunsic, Mtl	Lachine, Mtl	Kirkland	Rosemont, Mtl
Beaconsfield	Lasalle, Mtl	Notre-Dame-de-Grâce, Mtl	St. Leonard, Mtl
Boisbriand	St. Francois, Laval	Nouveau Rosemont, Mtl	Montreal, Town-of-Mount-Royal
Chambly	Duvernay, Laval	Parc-Extension, Mtl	Point St. Charles, Sud-Ouest, Mtl
Dollard-Des-Ormeaux	Longueil	Pierrefonds, Mtl	Rosemère
Dorval	Ahunsic, Montreal	Plateau Mont-Royal, Mtl	Longueil, South Shore
Gatineau	Montreal Ouest	Pointe-Claire	Brossard, South Shore
Greenfield Park, Longueil	Montreal North	Rivière-des-Prairies, Mtl	

Figure C.1 Island of Montreal boroughs (Ville de Montréal, 2008).

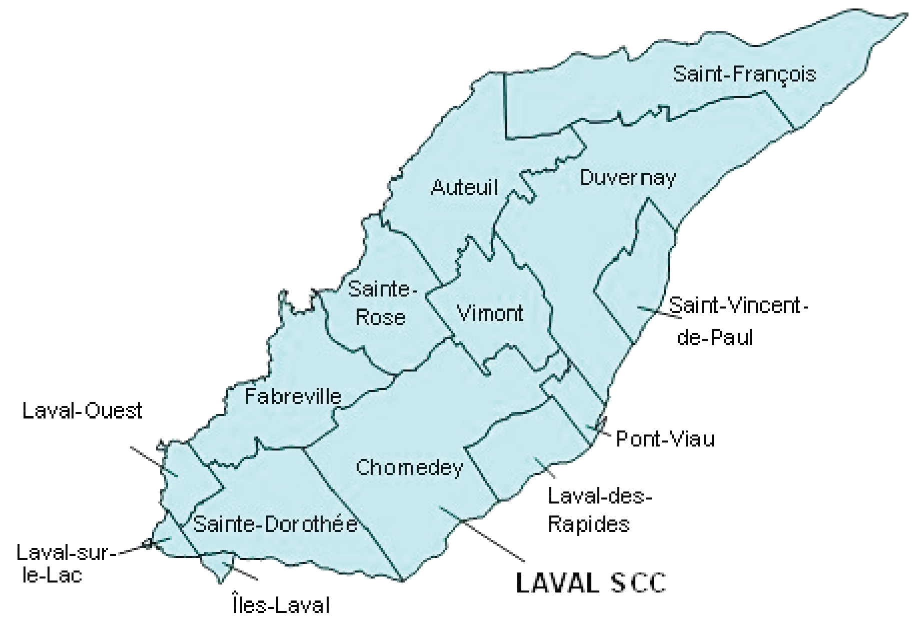


Figure C.2 Laval municipal structure (2002) (Service Canada, 2008).

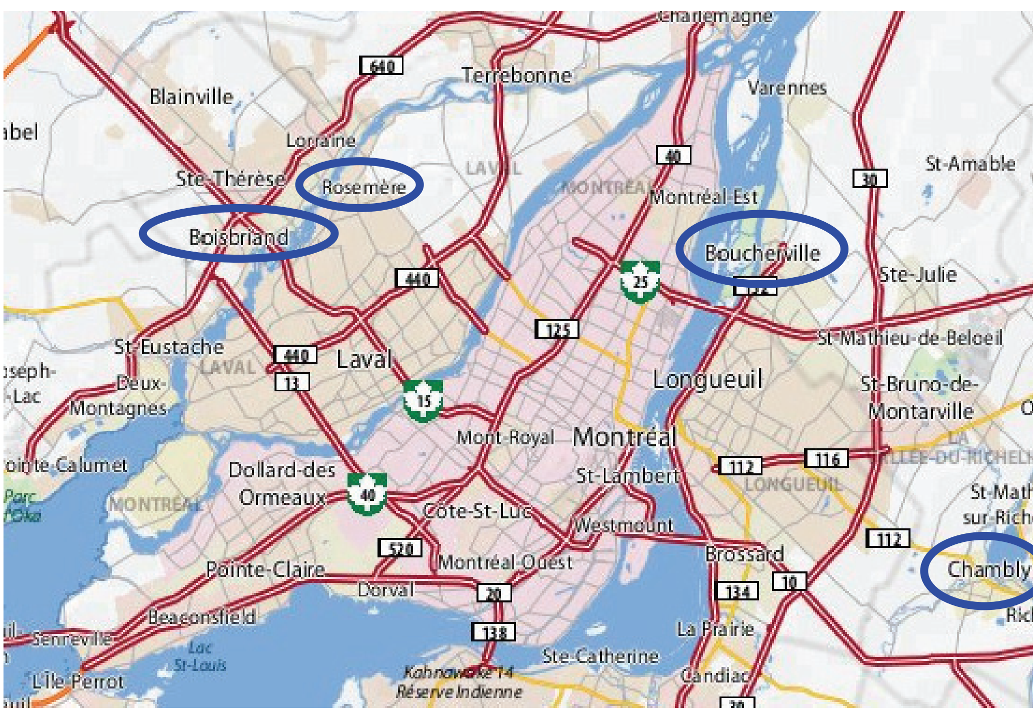


Figure C.3 Map of the Island of Montreal, Laval and surrounding Quebec municipalities (Yahoo Travel, 2008).

4) Do you believe that in regards to the infrastructure in Quebec, Quebecers are facing:

a) A small problem that can be overcome with increased government spending
b) An infrastructure crisis: more changes than just increased spending are needed to improve the state of our infrastructure!
c) An issue that is lately drawing too much media attention - the infrastructure in my community is in an acceptable state
d) We're facing problems with our infrastructure?

Responses:

Response	No. of Responses
a	6
b	52
c	1
d	5
Total	64

5) Would you say that events such as the 2006 De La Concorde and 2007 Minnesota Bridge Collapses, the 2002 pipe burst on Pie-IX boulevard and other tragic events have made you more concerned and aware of the importance of infrastructure systems for the functioning and safety of a community?

a) Definitely
b) Somewhat
c) Not at all

Responses:

Response	No. of Responses
a	51
b	11
c	2
Total	64

6) Which of the following main infrastructure categories would you consider are in the most deteriorated state and are in the greatest need for repair? Rank these from 1 to 6 (beside the given categories), where 1 is the infrastructure category with the greatest need for repair and 6 is the infrastructure category with the least need for repair. *This means that every infrastructure category should be numbered differently from 1 to 6.*

Water supply systems
Wastewater and stormwater systems
Transportation systems
Transit systems
Social, cultural, community and recreational facilities
Waste management systems

Responses:

	Ranking	1	2	3	4	5	6	Total Responses
Number of Responses	Water supply systems	17	22	7	7	7	4	64
	Wastewater and stormwater systems	3	15	23	11	11	1	64
	Transportation systems	35	11	8	9	1	0	64
	Transit systems	4	11	9	12	22	6	64
	Social, cultural, community and recreational facilities	2	0	3	5	11	43	64
	Waste management systems	3	5	14	20	13	9	64

7) Which of the following main infrastructure categories do you feel are negatively affecting Canada's international competitiveness, economic growth and the quality of life of Canadians due to their present state? Again, rank these from 1 to 6, where 1 is the infrastructure category with the greatest negative impact and 6 is the infrastructure category with the least impact. *Again, this means that every infrastructure category should be numbered differently from 1 to 6.*

Water supply systems
Wastewater and stormwater systems
Transportation systems
Transit systems
Social, cultural, community and recreational facilities
Waste management systems

Responses:

Number of Responses — Ranking	1	2	3	4	5	6	Total Responses
Water supply systems	7	14	17	14	5	7	64
Wastewater and stormwater systems	2	12	17	16	12	5	64
Transportation systems	36	11	7	7	2	1	64
Transit systems	11	18	6	7	13	9	64
Social, cultural, community and recreational facilities	3	5	7	7	9	33	64
Waste management systems	5	3	11	14	21	10	64

8) Are there specific types of infrastructure (i.e. roads, sidewalks, water distribution pipes, bridges, metro cars, treatment plants, etc.) that concern you? Please list these and in a few words list what concerns you the most.

In many cases responses to this question were repetitive, the majority of respondents felt that potholes, bridges and the overall state of our transportation systems are in an unacceptable state. Deteriorated water distribution pipes and transit systems were also primary concerns. For this reason, only partial responses are listed here forth (A complete list is available upon request):

- “Roads and sidewalks are of a major concern to me. They seem to be getting in worse condition year after year”
- “I would say that their proper management concerns me more than their state. Fixing things is not the solution. A sound maintenance plan is expected by all residents. Isn't that one of the main mandates of government? If Government isn't' taking care of the infrastructure they are providing, what are they doing? Also I feel that government management lacks vision. Instead of creating new roads, and tearing down old train lines we should be creating a better transit system. Taking more than an hour to get to work is not more acceptable than taking your car to get there. I suggest that a better transit system would bet a more appealing incentive to get off the roads than toll booths. That waste water still goes into the river is utterly unacceptable.I can go on and on here! “
- “Roads: where to begin? Cities basically apply a band-aid approach to road maintenance and repair.”
- “Bridges are getting old, and it is not common practice to plan for future maintenance. The same problem exists in the area of water distribution. This is particularly worrisome in Montreal’s extreme weather conditions – which would typically require more maintenance.”
- “Water distribution pipes- VERY OLD; Transportation Routes- NOT BUILT FOR THIS AMOUNT OF TRAFFIC; Bridges – OLD!”

- “Water distribution pipes and treatment plants because they can have great health risks both in the short and long term. Buses, metro cars and all transit systems because people are very dependent on them”
- “The bridges are what concerns me the most in today's society after all that has happened of late”
- “WASTE MANAGEMENT - encouraging reusing and recycling; minimizing waste, odors and toxicity in landfills; keeping the community clean and appealing are much needed.”
- “Given recent tragedies such as the De La Concorde overpass and Minneapolis Bridge collapses, there is growing concern for the overall state in which our infrastructure finds itself. I am pleased though by Montreal's investment to implement an ozonation facility to disinfect wastewater before it flows into the St.Lawrence!! An outcry to assess and improve the state of our infrastructure is becoming an increasingly important topic of discussion. Better late than never right?”
- “Transit - Costing more money but yet we are getting less service”
- “I feel that segments of roads are sometimes in such bad shape (generally pot-holes) that it becomes dangerous to drive. For example, you would try to avoid the pot-holes in order to not damage your car, but in doing so, you end up changing lanes quickly, almost causing an accident. Even if you stay in your lane, some pot-holes are just big enough to make you lose control of you car as you drive through it.”
- “The roads are in horrible shape because cheap substitute material is used to repair the roads (not even top grade asphalt is used let alone cement or other more durable materials). The Metro is stopped at least twice a week during rush hour, snow removal is also horrible (lack of storage space as well as long waiting periods makes snow removal a problem leading to increased transit, transport, and road problems).”
- “Environmental concerns are always an issue: are companies doing their part to build infrastructures that are environmentally friendly?”
- “What concerns me the most is the under-funding and the absence of a long-term plan that allowed our road transportation system to deteriorate, creating an economic and serious safety issue for Canadians.”
- “Snow removal!!!”
- “Metro system: breakdowns, staff/maintenance strikes, constantly increasing costs/fares”
- “Lack of compost pick-up (as they have in Toronto)”
- “Water distribution pipes: the City of Montreal repairs these in an ad-hoc manner (i.e. only when something breaks, which has been often in recent years). Granted the budget is not unlimited, but they only repair certain broken sections. In most cases, only half of a pipe is replaced while the old half remains. Furthermore, the City's reluctance to make water meters mandatory, especially for companies, contributes to the perception that nothing is really wrong with our pipes.”
- “Ask any truck driver where they like to drive their trucks/van the most. Not one of them will say the highways in Quebec are in good shape. I drive regularly between Montreal and Ottawa and take highway 417 (on the Ontario side). I've been taking this highway for more than 7 years now. It's always a pleasant drive and when you get on the Quebec side, watch out!; Watermains”
- “I question security measures in place especially when I am reminded of the E-Coli tragedy in Ontario. Roads - The obvious pothole situation seems to be getting worse. How about looking at long-term solutions instead of the band-aid approach; Water distribution pipes, in most places they are very old and water is leaking away!”

9) Would you be willing to pay a toll when driving over major Canadian bridges and highways, if it meant that the money would be used to implement routine maintenance programs of our major bridges and highways?

a) Definitely
b) Maybe
c) No Chance

Responses:

Response	No. of Responses
A	29
B	22
c	13
Total	64

Would you have had the same opinion if you were asked this question 10 years ago?

a) **Yes**
b) **No**
c) **Unsure or not applicable**

Responses:

Response	No. of Responses
a	28
b	19
c	17
Total	64

Willing to pay a toll	Same opinion 10 years ago	No. of Respondents
Definitely	Yes	15
Definitely	No	8
Definitely	Unsure or Not Applicable	6
Maybe	Yes	7
Maybe	No	10
Maybe	Unsure or Not Applicable	5
No Chance	Yes	6
No Chance	No	1
No Chance	Unsure or Not applicable	6

If you answered Maybe or No Chance, why? (Optional)

Most respondents felt that the Government would not use the collected funds appropriately to improve the infrastructure. They also claimed that they are already paying high taxes and gas prices. Partial responses follow:

- “It would depend on how expensive the tolls will be, and I'm somewhat unsure if the government would actually put the money to good use.”
- “I pay enough in taxes! Perhaps better management of funds is in order!”
- “The money is already there, the Government should use it appropriately”
- “I'm much more informed today about the benefits of privatization infrastructure”
- “I don't feel that the government has shown responsible spending in infrastructure so far. If the government can prove that it has done its maximum to optimize its spending and optimize infrastructure conditions, then I may be willing to contribute an additional amount, on condition that there remains toll-free alternatives.”
- “I believed that we Québécois are paying way enough taxed as is. The question should rather be how could our Governments better manage our actual tax money to permit the gradual improvement of the infrastructures. (This should have started years ago and improvements done gradually, then we would not face the actual crisis).”
- “It is so hard to trust where the money will go.”
- “Our current budgets should include routine maintenance programs as to protect the safety and lives of individuals. I don’t see the problem as being a budget problem, but rather a problem that extends to the policies, procedures, and capabilities of government to implement the right programs that provide timely and accurate results.”
- “I feel like a larger part of the taxes on gasoline should go to road repair...driving is already so costly that the thought of having tolls is worrisome”
- “We are already paying more than enough to maintain the roads through gas tax, licence plate fees, driver’s permits and so on. It's just that the money is used to finance other programs or partisan issues (e.g. from what we heard the De La Concorde bridge cost 4 million to rebuild and 6 million for the inquiry). Also when a contract, whether for maintenance or new construction, is given it's always to the lowest bidder and no supervision of the work. No one wants to be held responsible for decisions or actions they take but that we have to live with. This results in the present state of our infrastructures and more expensive in the long term for the taxpayers.”

10) Would you accept the installation of watermeters (A water meter is a small box outside your home that measures the amount of water used in your home. The user then pays according to the amount of water consumed) in your community if it meant that the money would be used to implement routine maintenance of the water distribution systems, sewage disposal systems and water treatment facilities in your community?

a) Definitely
b) Maybe
c) No Chance

Responses:

Response	No. of Responses
A	28
B	26
C	10
Total	64

Would you have had the same opinion if you were asked this question 10 years ago?

d) Yes
e) No
f) Unsure or not applicable

Responses:

Response	No. of Responses
A	36
B	11
C	17
Total	64

Accept the installation of watermeters	Same opinion 10 years ago	No. of Respondents
Definitely	Yes	18
Definitely	No	7
Definitely	Unsure or Not Applicable	3
Maybe	Yes	10
Maybe	No	4
Maybe	Unsure or Not Applicable	12
No Chance	Yes	8
No Chance	No	0
No Chance	Unsure or Not applicable	2

If you answered Maybe or No Chance, why? (Optional)

Again, as with the tolls, respondents repetitively stated that they are concerned that collected funds will not be used appropriately. Partial responses follow:

- "Before we pay more money our existing taxes should be used appropriately"

- "Before instating the tax though, I would continue programs in order to try to educate people. If this would succeed we would all gain from it in the long term by having more waste conscious people in our society."
- "I would only accept this if companies and corporations pay the same tax. If it's a citizen tax, they can kiss it goodbye."
- "This may imply that those communities who are "water conscious" will be neglected when it comes to routine maintenance since their consumption (and thus their contribution in dollars) will be less than high-consuming communities."
- "I believe that water should be controlled and monitored but I have a hard time believing that all collected money would go towards water facilities and related maintenance."
- "Again I believe that we pay way enough taxes as is, but regarding water usage I would be more open to pay a certain extra amount or by usage due to the fact that many families are still not water conscientious at all and waste way to much water."
- "After working in municipal waterworks, I realize how much potable water is wasted by people. A lot of it is also wasted in watermain leaks in the water distribution network. I was not really aware of this several years ago."
- "This must not be additional. If part of our current tax is removed and we get to pay for what we use, then it appears more likely."

11) How would you rank the following impediments to successful rehabilitation and maintenance of our infrastructure? (1 = greatest impediment, 6 = least impediment)

Funding shortage;
Political inaction;
Red Tape;
Lack of qualified personnel;
Lack of knowledge about the problems associated to inadequate upkeep and management of infrastructure by politicians;
Lack of knowledge about the problems associated to inadequate upkeep and management of infrastructure by the community

Responses:

	Ranking	1	2	3	4	5	6	Total Responses
Number of Responses	Funding shortage;	7	14	17	14	5	7	64
	Political inaction;	2	12	17	16	12	5	64
	Red Tape;	36	11	7	7	2	1	64
	Lack of qualified personnel;	11	18	6	7	13	9	64
	Lack of knowledge about the problems associated to inadequate upkeep and management of infrastructure by politicians;	3	5	7	7	9	33	64
	Lack of knowledge about the problems associated to inadequate upkeep and management of infrastructure by the community	5	3	11	14	21	10	64

12) What are your primary concerns, if any, about the state of our infrastructure? Please list these. (Optional)

Most respondents expressed their concern that another infrastructure-related tragedy will occur. Educating the public and the politicians, enforcing routine maintenance plans and looking towards innovative financing were among the needs expressed. Political inaction and needed changes to the current civil engineering/infrastructure management practices are also specified. Partial responses follow (A complete list is available upon request):

- "How long before the next unfortunate list of events?"
- "How seriously are we looking into this situation?"
- "Are any of the politicians willing to do what has to be done regardless of their political future? Of course not!"
- "My biggest concern is that nothing is going to get done before things get worse (i.e. it will get worse before it gets better)."
- "What bothers me most is knowing the money is there. But somehow action is not taken. Instead we are having typical answers like 'it's the temperature in Quebec, we don't have enough resources, money…"
- "I worry that the essential issue of enforcing a maintenance plan will not be addressed soon enough"
- "Lack of creative financing models, uninformed politicians making key decisions about fund allocation and inadequate operation and maintenance during infrastructure life-cycle."
- "Public safety, efficient and reliable systems, continuous monitoring, impact on the environment"
- "Public unawareness...we seem to be moving away from democracy (where's the public say in all of this?)"
- "Lack of knowledge about problems associated to the upkeep of infrastructure."
- "Taxes, tolls, and other charges expected to be for one thing, yet being used for other things and we are still in debt! Money never seems to go where it's supposed to. We get taxed so much, yet can never manage to improve anything!!!"
- "That it will take a serious accident (foreseen or unforeseen) or severe negative economic impact on the city to incite any action on the part of government."
- "Go private, that's probably the best solution. Contract private companies or firms to build the roads, transit lines and so on and have the above person in charge (government) who will have it organized, make sure if something does begin to break or deteriorate."
- "Reluctance of the people in a position to do something to actually do something."
- "Conventional thinking with one's wallet. People (including politicians, executives, academics) lack the creativity to seek alternative ways of spending a dollar."
- "The scapegoating of engineers. This involves the absolution of responsibility by everybody involved. It is to cover one's reputation above anything else, including admitting any negligence or wrongdoing."
- "Especially in Quebec, the low-bid approach and the lack of any responsibility for contractors after a certain time period."
- "The lack of any technical knowledge by administrative people. These are the people most often making important decisions."
- "Education in general. New techniques and technologies exist. That is the greatest quality of our kind yet we somehow manage to live in the past. People are reluctant whether by ignorance or fear to adopt new practices or materials. A greater effort should be made by engineers, architects, scientists and academics to connect with the people who are actually carrying out the work."

- "Impacts not only on our future, but that of the generations to come; possible loss of life due to un-safe structures or conditions; impact on sanitary conditions such as clean drinking water; impact on the economy."
- "The deficit is compounding, we need to act fast and consistently in order to stabilize this."
- "Not enough money/funding is being diverted into infrastructure asset management in general. More awareness programs should be put in place to encourage people not to waste potable water for instance."
- "Politicians spend funds on what they think will get them re-elected, not the proper administration of the infrastructure they provide. If someone yells loudly enough and conjures up enough fuss from citizens about the color of the paint in the public pool, that is what will be taken care of, whether the predetermined budget had any money set aside for that or not."

13) The infrastructure deficit is the difference between the funding needed for maintenance, repair, rehabilitation and replacement of existing deteriorated infrastructure and the funding available from all sources, including taxes, government subsidies and grants, private sector contributions, etc. If you had to estimate where our municipal infrastructure deficit stood today, which of the following groups would you select:

<$50 billion
$50 - $75 billion
$75 - $100 billion
$100 - $125 billion
$125 - $150 billion
$150 - $175 billion
$175 – $200 billion
>$200 billion
>$1trillion

Responses:

Deficit	No. of Responses
<$50 billion	5
$50 - $75 billion	4
$75 - $100 billion	10
$100 - $125 billion	12
$125 - $150 billion	11
$150 - $175 billion	9
$175 – $200 billion	7
>$200 billion	6
>$1trillion	0
Total	64

Appendix D

Table D.1 Canadian Infrastructure Programs – 1919 to 2007

Program/Act	Investment	Objectives	Main Outcomes
Canada Highways Act (1919-1928) (Facette, 1998)	▪ $20 million total ▪ $80,000/year/province ▪ Remainder allocated based on population of provinces ▪ Federal-provincial share: 40-60	▪ "To stimulate construction, coordinate provincial activity and achieve some uniformity of road standards"	▪ 40,000 km of highway (Encyclopedia Britannica, 2007) ▪ Federal government rejected the provinces' request to extend the program (Turgeon and Vaillancourt, 2002)
Unemployment Relief Act (1930-1937) (Facette, 1998)	▪ $48.3 million	▪ To provide employment after the 1929 Depression	▪ Increased employment in local construction industries ▪ Public works projects to increase employment
Municipal Improvements Assistance Act (1938-1949) (Preville, 2004)	▪ $30 million in loans maximum ▪ $7 million was provided	▪ To provide loans to municipalities at 2% interest rates	▪ Municipalities were able to carry out necessary self-liquidating projects to improve public works
Bill 212 - Trans-Canada Highway (TCH) Act (1949-1971) (CBC, June 5 2007)	▪ $300 million total ▪ Expected federal-provincial share: 50-50 ▪ Final total federal share: 66.6%	▪ To authorize the cost-shared commitment of the federal and provincial governments to build a national highway ▪ To provide a highway from the Atlantic to the Pacific, to link Canada's provinces and major cities	▪ The world's longest national highway - 7,821 km ▪ New branches added ever since - 12,950 km (in 1999) ▪ Total construction costs over $1 billion ▪ TCH officially completed in 1970 - 14 years after expected completion ▪ Today, major upgrades are needed: 26 deaths and more than 900 accidents (1988-1998) on stretch between Gull Lake and Alberta border due to needed upgrading

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Road to Resources Program: The Northern Roads Program & The Northern Road Network Program (1957-1975) (Turgeon and Vaillancourt, 2002)	▪ Over $200 million (both programs combined)	▪ To establish road networks in remote areas of northern Canada ▪ To provide accessibility to areas rich in resources ▪ To construct and improve existing road networks in the Yukon and the Northwest /territories	▪ The 736 km Dempster Highway from Dawson City, Yukon to Inuvik, NWT (McCready, 1979) ▪ Construction delays due to changing federal government priorities (McCready, 1979) ▪ A boom in gas and oil exploration ▪ The Northern Roads Program from 1958 was reinstated as the Northern Road Network Program
Sewage Treatment Program (1961-1974) (Facette, 1998)	▪ $979 million in loans ▪ $131 million in grants	▪ To finance the construction of sewage treatment and collection systems	▪ (Information not available) ▪ Improved water quality in some communities, yet many other areas still lack adequate sewage
Municipal Development & Loan Act (1963-1966) (Infrastructure Canada, June 7 2007)	▪ $400 million in loans	▪ "To promote increased employment and production […] by offering loans and incentives to municipalities to accelerate and expand their capital works programs"	▪ 2,429 loans approved for 1,262 municipalities ▪ Total loans: $396,952,194 ▪ One third of the fund used to finance water and sewer projects ▪ Equal amount used to upgrade schools, roads and bridges, transit systems and civic administration buildings ▪ Other projects funded: park developments, recreation facilities, hospitals, and power distribution projects

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Atlantic Development Board Trunk Program (1964-1969) (Turgeon and Vaillancourt, 2002)	▪ Over $60 million in grants	▪ To promote economic growth in the Atlantic provinces (Nova Scotia, P.E.I, New Brunswick, Newfoundland) ▪ To improve the region's road network	▪ Construction of new roads, power plants, research facilities and industrial parks
National Transportation Act (NTA) (1967) (Turgeon and Vaillancourt, 2002)	▪ (N/A)	▪ To change the role of the federal government in the area of transportation	▪ Creation of the Canadian Transport Commission (CTC) ▪ The part of the NTA stressing the federal government's constitutional responsibilities for the motor-carrier industry was not implemented ▪ The industry was left in the hands of the provincial government and therefore the federal government's incentives to improve highway policies did not change ▪ (Numerous amendments since 1967)
Outaouais Road Agreement Contribution Program (ORA) (1972 -) (Transport Canada, 2005)	▪ $207 million (1972-2004) ▪ Share: 50 (federal), 50 (provincial)	▪ To improve the level of service of the road system in Outaouais, Qc ▪ "To reduce the inequality between the road networks in the Ontario and Quebec parts of the [National Capital Region] NCR"	▪ Projects include the improvement of 3 highway systems, 8 urban arteries, and 5 other projects involving road improvement and expropriation (Transport Canada, June 17 2007)
Neighborhood Improvement Programs (1973-1983) (Preville, 2004)	▪ $100 million in loans ▪ $200 million in grants	▪ To provide funding for water and sewer systems, parks, etc. ▪ Rehabilitation of homes, under a housing program by the Canada Mortgage and Housing Corporation (CMHC)	▪ Upgrading and preservation of older neighborhoods – 270 neighborhoods improved ▪ Participation by 125 towns and cities across Canada ▪ Over 310,000 houses rehabilitated (Wolfe, 1994)

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Neighborhood Improvement Programs (1973-1983) (Preville, 2004)	▪ $100 million in loans ▪ $200 million in grants	▪ To provide funding for water and sewer systems, parks, etc. ▪ Rehabilitation of homes, under a housing program by the Canada Mortgage and Housing Corporation (CMHC)	▪ Upgrading and preservation of older neighborhoods – 270 neighborhoods improved ▪ Participation by 125 towns and cities across Canada ▪ Over 310,000 houses rehabilitated (Wolfe, 1994)
Western Northland Highway Program (1974-1981)	(There has been mention of these programs in the literature, but no other information available)		
Prairies Provinces Primary Highways Strengthening Program (1974-1979)			
Municipal Infrastructure Program (1975-1978) (Facette, 1998)	▪ $1 billion in loans ▪ $395 million in grants	▪ "Pollution abatement, sewage treatment and land development"	
Atlantic Provinces Primary Highway Strengthening/Improvement Program (1977-1988) (Turgeon and Vaillancourt, 2002)	▪ $221 million in grants ▪ A 50-50 federal-provincial share (75-25 for Newfoundland between 1982-1988)	▪ Phase I: To increase uniform truck load limits in the Atlantic provinces – consistent with those of other provinces ▪ Phase II: To promote economic development in the Atlantic provinces by improving the highway system (i.e., maintain road safety, improve transport and traffic flow) (OAG, 1986)	▪ Approximately $1 million for program evaluation (provinces) ▪ Phase I: improved trucking and lower truck rates as a result of improved highways ▪ (Further information unavailable) (OAG, 1986)

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Community Services Contribution Program (1979-1980) (Preville, 2004)	▪ $400 million in grants	▪ To provide funding for projects related to sewer and water distribution , social and recreational programs, etc.	▪ (Further information unavailable)
Employment Creation Grants and Contributions Program (ECGC) (1982-1986) (OAG, 1986)	▪ $205 million in grants or contributions	▪ To reduce unemployment ▪ "To fund labour intensive projects within the existing government programs"	▪ Funded 2,146 projects ▪ 96% funded by grants ▪ ECGC continued in 1986-87 to complete 20 projects ▪ Projects included: "the construction or improvement of sewers, city halls, bridges, roads, sidewalks, parks, industrial parks, sports and recreation centers and churches."
Special Recovery Capital Projects Program (SCRPP) (1984-1994)	▪ $194 million in grants ▪ Federal-provincial share: 70-30 (N.B.), 50-50 (P.E.I.), 62.5-37.5 (Newfoundland) and 50-50 (QC)	▪ To provide assistance in the construction, strengthening and improvement of provincial highways, secondary and access roads under the special recovery capital projects program ▪ To enlarge, strengthen and therefore improve the provincial highway network	▪ Projects included the construction of the Salmon Beach Bypass in N.B. (Transport Canada, June 17 2007) ▪ (Further information unavailable)
Yellowhead Highway Improvement Program (1987-1992) (Turgeon and Vaillancourt, 2002)	▪ $50 million in grants ▪ Federal-provincial share: 50-50 (Manitoba, Saskatchewan, Alberta, B.C.)	▪ To enlarge, strengthen and therefore improve the provincial highway network ▪ To increase and standardize the vehicle mass limit to ensure safe and efficient movement of goods and people across the provinces	▪ B.C.: 7 rehabilitation projects on 2 highways ▪ Alberta: 6 projects on a highway and a truck route (grading and paving) ▪ Saskatchewan: 3 projects involving twinning, 3 safety-related projects, and 5 projects involving structural rehabilitation and resurfacing ▪ Manitoba: Interchange and Intersection Improvements (capacity and safety-related)

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Yellowhead Highway Improvement Program (1987-1992) (Turgeon and Vaillancourt, 2002)	▪ \$50 million in grants ▪ Federal-provincial share: 50-50 (Manitoba, Saskatchewan, Alberta, B.C.)	▪ To enlarge, strengthen and therefore improve the provincial highway network ▪ To increase and standardize the vehicle mass limit to ensure safe and efficient movement of goods and people across the provinces	▪ B.C.: 7 rehabilitation projects on 2 highways ▪ Alberta: 6 projects on a highway and a truck route (grading and paving) ▪ Saskatchewan: 3 projects involving twinning, 3 safety-related projects, and 5 projects involving structural rehabilitation and resurfacing ▪ Manitoba: Interchange and Intersection Improvements (capacity and safety-related projects)
Highway Improvement Programs (1987-1998) (Turgeon and Vaillancourt, 2002)	▪ \$307 million in grants ▪ Federal-provincial share: 70-30 (N.B., Manitoba)	▪ To enlarge, strengthen and therefore improve the provincial highway network	▪ Manitoba: 21 projects on 4 highways (resurfacing, grading, twinning) and 5 projects related to improving planning, communication and evaluation (i.e., geometric design guide, a pavement condition survey, etc.) ▪ N.B.: 12 projects to improve the national highway system and one project related to planning, evaluation and communication (Transport Canada, June 17, 2007)
Newfoundland Transportation Initiative (1987-2003) (Turgeon and Vaillancourt, 2002)	▪ \$640 million ▪ Federal-provincial share: 100-0 (Newfoundland)	▪ To enlarge, strengthen and therefore improve the provincial highway network	▪ (Further information unavailable)

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Cooperation Agreement for Transportation Development (1988-1994) (Padova, 2006)	▪ $15 million (federal allocation)	(Further information unavailable)	
Trans Canada Highway Program (TCH) (1988-2003) (Padova, 2006)	▪ $389 million	▪ To improve the Trans Canada Highway post closure of the Newfoundland railway (Transport Canada, June 17 2007)	▪ Construction of additional lanes ▪ Resurfacing and widening of certain sections ▪ Other repairs and rehabilitation
Public Highways Act (1989)	▪ (N/A)	▪ Applies to highways within a province, not within borders of cities or towns or owned by a municipality	▪ (Numerous amendments since 1989)
Federal Infrastructure Works Program (1993-1998) (Siddiqui, 1997)	▪ $6 billion (partnership between the three levels of government) ▪ Allocation based equally on population and unemployment rate	▪ To accelerate economic recovery by providing short-and long-term jobs by investing in local communities ▪ To upgrade municipal infrastructure through job creation in the area of infrastructure	▪ 12,000 projects ▪ 10,000 jobs created (Government of Newfoundland and Labrador, 1997) ▪ Projects funded include: water treatment and distribution systems, sewage and drainage facilities, earthworks, road networks, public facilities ▪ Boost in the economy and improved standard of living ▪ 60% of funding towards new construction
Strategic Capital Investment Initiative-Highways (1993-1999) (Transport Canada, 2000)	▪ Total estimated cost: $579 million in grants ▪ Actual investment: $6.6 million ▪ Federal-provincial share: 50-50 (All provinces except P.E.I.)	▪ Improving the national transportation system	▪ Actual money spent = $6.6 million ▪ (Further information unavailable)

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Canada Infrastructure Works Program (CIWP) (1993-1998) (Preville, 2004)	▪ \$2.43 billion ▪ (\$2 billion by federal government and \$4 billion by provinces and territories in matching funds)	▪ To promote the development and maintenance of municipal infrastructure. Namely the upgrading of water and sewer systems, roads, bridges and public buildings	▪ Was to initially last 2 years but was extended ▪ The final 3 years were without funding ▪ 81,000 person years of employment ▪ 61,000 direct jobs ▪ 120,000 indirect jobs (Stefanson, 1998)
Fixed Link Highway Improvement Agreement (FLNK) (1994-1998)	▪ \$43 million in grants ▪ Federal-provincial share: 100-0 (N.B., P.E.I.)	▪ To provide funding to assist in dealing with increased highway congestion – post construction of the Confederation Bridge (i.e., increase capacity and improve safety of highway system)	▪ The rehabilitation of 16 roads ▪ Construction of McAuslands Bridge ▪ Bridge repairs and rehabilitation projects ▪ Lane expansion projects (Preville, 2004)
Atlantic Region Freight Assistance Transition Program (1995-2001) (Turgeon and Vaillancourt, 2002)	▪ \$326 million ▪ Federal-provincial share: 100-0 (N.B., N.S., P.E.I., QC)	▪ To assist the provinces with improving their highway system – post abolition of the Atlantic Region Freight Assistance Act and the Maritime Freight Rates Act ▪ To increase the productivity of the transportation system	▪ Projects include improving the geometry and drainage, as well as performing rehabilitation and reconstruction of 7 major highways ▪ The rehabilitation of other road networks and bridges ▪ Providing shipper assistance (100% federal funding) (Transport Canada, June 17 2007)
Canada Agri-Infrastructure Program (CAIP) (1996-2001) (Turgeon and Vaillancourt, 2002)	▪ \$140 million in grants ▪ Federal-provincial share: 100-0 (B.C., Alberta, SK, Manitoba)	▪ To improve agriculture-related infrastructure across Western Canada	▪ Large contributions to improving road and highway infrastructure required by new grain transportation patterns ▪ Both new construction and rehabilitation ▪ Closure of many rail branch lines

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Canada Agri-Infrastructure Program (CAIP) (1996-2001) (Turgeon and Vaillancourt, 2002)	▪ $140 million in grants ▪ Federal-provincial share: 100-0 (B.C., Alberta, SK, Manitoba)	▪ To improve agriculture-related infrastructure across Western Canada	▪ Large contributions to improving road and highway infrastructure required by new grain transportation patterns ▪ Both new construction and rehabilitation ▪ Closure of many rail branch lines
Infrastructure Canada Program (ICP) (2000-2007) (Preville, 2004)	▪ $2.05 billion ▪ ($1.975 billion to fund program, remainder for administrative costs)	▪ Improve municipal infrastructure ▪ Focus on water and wastewater treatment systems, roads and highways ▪ A strong emphasis on "green" municipal infrastructure ▪ Target small local projects	▪ Over 3,500 ICP projects have been announced ▪ Replaced the CIWP in 2000 budget

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Federation of Canadian Municipalities Green Municipal Funds (GMF) (2000-) (Preville, 2004)	▪ $550 million (FCM, 1997)	▪ To fund environmental infrastructure projects ▪ To help reduce pollution and greenhouse gas emissions ▪ To improve air, water and soil quality ▪ To promote the use of renewable energy	▪ 600 studies, field test, plans and capital projects approved for funding so far (Ongoing) ▪ Generated over $1.9 billion in economic activity in over 300 communities (FCM, June 25 2007)
Cultural Spaces Canada Program (2001-2004) (Preville, 2004)	▪ $80 million ▪ (An average $2.43/capita)	▪ To "support the improvement, renovation, and creation of arts and heritage facilities, as well as specialized equipment purchases and feasibility studies" ▪ Improved accessibility to museums, arts and heritage facilities, and other cultural spaces	▪ 210 projects funded
Prairie Grain Road Programs (PGRP) (2001-2006) (Preville, 2004)	▪ $175 million (Federal)	▪ To improve the condition of roads used to transport grain in the Prairie Provinces and in the Peace River region of B.C. ▪ Roads include municipal, rural and secondary provincial roads/highways in Manitoba, Saskatchewan, Alberta, and British Columbia	▪ $318.5 million in road construction in Western Canada (through federal, provincial and municipal government contributions) (Agriculture and Agri-Food Canada, 2007)

Strategic Highway Infrastructure Program (SHIP)
(2001-2005)
 	
(Preville, 2004)
	▪ $600 million ($500 million - highway construction, $100 million - improve national highway system, $15 million - administrative costs)
	▪ Extra $100 million for strategic initiatives
	▪ Minimum of $4 million/jurisdiction plus additional share based on population
		▪ To improve highway construction and the national highway system
		▪ To fund strategic initiatives (i.e., Intelligent Transportation Systems - ITS, improved transportation planning, etc.)
		▪ "To support trade, tourism and investment in Canada"
			▪ Numerous projects related to:
			  ▪ Intelligent Transportation Systems
			  ▪ Highways
			  ▪ Borders

Table D.1 (Continued)

Program/Act	Investment	Objectives	Main Outcomes
Canada Strategic Infrastructure Fund (2001-)	▪ $2 billion ▪ Additional $2 billion in 2003 budget	▪ To fund larger-scale national infrastructure projects ▪ To encourage more partnerships in order to meet national needs ▪ To help meet climate change objectives and encourage sustainable development	▪ Investments were established based on populations ▪ Investments in five categories 1) highway and railway, 2) local transportation, 3) tourism or urban development, 4) water and sewage and 5) broadband infrastructure ▪ (Ongoing)
Border Infrastructure Fund (BIF) (2002-2013) (Preville, 2004)	▪ $600 million	▪ To help minimize congestion and increase efficiency/capacity at the U.S.-Canada border ▪ "Support Initiatives under the Smart Borders Action Plan" ▪ Ensure the secure flow of people and goods	▪ (Ongoing)
Rural Municipal Infrastructure Fund (RMIF) (2004-) (Preville, 2004)	▪ $1 billion ▪ $15 million/province or territory ▪ Remainder allocated based on population	▪ To create a balance between the infrastructure needs of rural and urban communities	▪ 80% of funding to municipalities with populations less than 250,000 ▪ Remainder of funding to municipalities with populations between 25,000 and 250,000 ▪ (Ongoing)
Building Canada Plan (2007-2014) (Government of Canada, 2007)	▪ $33 billion	▪ To support infrastructure owned by the three levels of government ▪ Experiment with new financing alternatives ▪ Expand new gateways and corridors ▪ Support the Asia-Pacific Gateway and Corridor Initiative	▪ (Ongoing)