Decision Making and Investment Planning

Investment Parameters For Municipal Infrastructure

This document is the sixth in a series of best practices that transform complex and technical material into non-technical principles and guidelines for decision making. For titles of other best practices in this and other series, please refer to *www.infraguide.ca.*

National Guide to Sustainable Municipal Infrastructure

NRC · CNRC Federation of Canadian Municipalities Canada

Investment Parameters for Municipal Infrastructure

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INTRODUCTION

InfraGuide – Innovations and Best Practices

Why Canada Needs InfraGuide

Canadian municipalities spend $12 to $15 billion annually on infrastructure but it never seems to be enough. Existing infrastructure is ageing while demand grows for more and better roads, and improved water and sewer systems responding both to higher standards of safety, health and environmental protection as well as population growth. The solution is to change the way we plan, design and manage infrastructure. Only by doing so can municipalities meet new demands within a fiscally responsible and environmentally sustainable framework, while preserving our quality of life.

This is what the National Guide to Sustainable Municipal Infrastructure (InfraGuide) seeks to accomplish.

In 2001, the federal government, through its Infrastructure Canada Program (IC) and the National Research Council (NRC), joined forces with the Federation of Canadian Municipalities (FCM) to create the National Guide to Sustainable Municipal Infrastructure (InfraGuide). InfraGuide is both a new, national network of people and a growing collection of published best practice documents for use by decision makers and technical personnel in the public and private sectors. Based on Canadian experience and research, the reports set out the best practices to support sustainable municipal infrastructure decisions and actions in six key areas: 1) municipal roads and sidewalks 2) potable water 3) storm and wastewater 4) decision making and investment planning 5) environmental protocols and 6) transit. The best practices are available on-line and in hard copy.

A Knowledge Network of Excellence

InfraGuide's creation is made possible through $12.5 million from Infrastructure Canada, in-kind contributions from various facets of the industry, technical resources, the collaborative effort of municipal practitioners, researchers and other experts, and a host of volunteers throughout the country. By gathering and synthesizing the best Canadian experience and knowledge, InfraGuide helps municipalities get the maximum return on every dollar they spend on infrastructure — while being mindful of the social and environmental implications of their decisions.

Volunteer technical committees and working groups — with the assistance of consultants and other stakeholders — are responsible for the research and publication of the best practices. This is a system of shared knowledge, shared responsibility and shared benefits. We urge you to become a part of the InfraGuide Network of Excellence. Whether you are a municipal plant operator, a planner or a municipal councillor, your input is critical to the quality of our work.

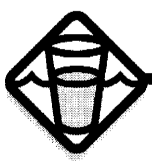
Please join us.

Contact InfraGuide toll-free at **1-866-330-3350** or visit our Web site at ***www.infraguide.ca*** for more information. We look forward to working with you.

The InfraGuide Best Practices Focus

Decision Making and Investment Planning

Current funding levels are insufficient to meet infrastructure needs. The net effect is that infrastructure is deteriorating rapidly. Elected officials and senior municipal administrators need a framework for articulating the value of infrastructure planning and maintenance, while balancing social, environmental and economic factors. Decision-making and investment planning best practices transform complex and technical material into non-technical principles and guidelines for decision making, and facilitate the realization of adequate funding over the life cycle of the infrastructure. Examples include protocols for determining costs and benefits associated with desired levels of service; and strategic benchmarks, indicators or reference points for investment policy and planning decisions.



Potable Water

Potable water best practices address various approaches to enhance a municipality's or water utility's ability to manage drinking water delivery in a way that ensures public health and safety at best value and on a sustainable basis. Issues such as water accountability, water use and loss, deterioration and inspection of distribution systems, renewal planning and technologies for rehabilitation of potable water systems and water quality in the distribution systems are examined.

Environmental Protocols

Environmental protocols focus on the interaction of natural systems and their effects on human quality of life in relation to municipal infrastructure delivery. Environmental elements and systems include land (including flora), water, air (including noise and light) and soil. Example practices include how to factor in environmental considerations in establishing the desired level of municipal infrastructure service; and definition of local environmental conditions, challenges and opportunities with respect to municipal infrastructure.

Storm and Wastewater

Ageing buried infrastructure, diminishing financial resources, stricter legislation for effluents, increasing public awareness of environmental impacts due to wastewater and contaminated stormwater are challenges that municipalities have to deal with. Storm and wastewater best practices deal with buried linear infrastructure as well as end of pipe treatment and management issues. Examples include ways to control and reduce inflow and infiltration; how to secure relevant and consistent data sets; how to inspect and assess condition and performance of collections systems; treatment plant optimization; and management of biosolids.

Transit

Urbanization places pressure on an eroding, ageing infrastructure, and raises concerns about declining air and water quality. Transit systems contribute to reducing traffic gridlock and improving road safety. Transit best practices address the need to improve supply, influence demand and make operational improvements with the least environmental impact, while meeting social and business needs.

Municipal Roads and Sidewalks

Sound decision making and preventive maintenance are essential to managing municipal pavement infrastructure cost effectively. Municipal roads and sidewalks best practices address two priorities: front-end planning and decision making to identify and manage pavement infrastructures as a component of the infrastructure system; and a preventive approach to slow the deterioration of existing roadways. Example topics include timely preventative maintenance of municipal roads; construction and rehabilitation of utility boxes; and progressive improvement of asphalt and concrete pavement repair practices.

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ACKNOWLEDGEMENTS

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This best practice was developed by stakeholders from Canadian municipalities and specialists from across Canada, based on information from a scan of municipal practices and an extensive literature review. The following members of the National Guide's Decision Making and Investment Planning (DMIP) Technical Committee provided guidance and direction in the development of this best practice. They were assisted by the Guide Directorate staff and by New East Consulting Services Ltd.

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EXECUTIVE SUMMARY

This document outlines best practices for the application of investment parameters to support objective, value-based and community driven investment decisions needed to preserve, sustain and renew municipal infrastructure to meet the needs and expected levels of service of individual communities, accounting for technical and financial constraints. Best practices have been identified and presented based on literature and web search, questionnaire survey and the personal experience of working group members and consultants.

The document presents a framework to aid municipalities in their decision-making processes dedicated to infrastructure investment planning and renewal programs. It describes 1) benefits of timely and cost-effective infrastructure investment as well as the risk of non-renewal of these assets, 2) an infrastructure asset reporting model that captures leading accounting practices in preparing annual financial statements in the United States and Canada, 3) two sets of high-level and detailed-level investment parameters along with their respective applications, and 4) improved communication between elected officials and the public as well as elected officials and technical and professional teams. The document also highlights its limitations and identifies further research needs.

The two sets of investment parameters, described in this document, provide guidance to municipalities in estimating annual budgets required to sustain their infrastructure assets considering the type, condition rating, expected life, replacement cost, operating conditions, and expected levels of service of these assets. The parameters can also be used to effectively communicate investment decisions to elected officials and the public.

The best practices outlined in this document include:

- The infrastructure asset financial reporting guide recommended by the Canadian Institute of Chartered Accountants;
- High level investment parameters, such as the estimated replacement value, expected life, and condition rating class/level of infrastructure and their application to prepare multi-year infrastructure renewal programs;
- Detailed level investment parameters, such as the probability of failure, renewal priority index, unit cost per year of life extension and non-renewal risk index and their application to prioritizing the specific project items within the established infrastructure renewal programs; and
- Communication of infrastructure renewal benefits and non-renewal risks with senior management, elected officials, and the public to receive adequate funding.

The entire topic of investment parameters and their applications relative to municipal infrastructure is broad and generally uncharted. Accordingly, this Best Practice is an initial effort, and as such, the investment parameters referred to should not be construed as either exhaustive or wholly definitive. Recognition of the need for additional effort in this area is paralleled with the anticipation of supplementary related developments.

1. General

1.1 Purpose and Scope

The Federation of Canadian Municipalities (FCM) and the National Research Council (NRC) have joined in a partnership to produce the *National Guide to Sustainable Municipal Infrastructure* (InfraGuide). To protect and enhance the quality of life, the InfraGuide identifies and disseminates best practices and encourages innovation to support sustainable municipal infrastructure decisions and actions.

This best practice document, developed under the guidance of the Decision-Making and Investment Planning Technical Committee, aims to introduce to Canadian municipalities decision support methods needed to achieve adequate levels of investment in municipal infrastructure. This best practice is based on a questionnaire survey of financial and technical parameters used by Canadian and international municipalities/regions to make investment decisions on municipal infrastructure associated with roads, drinking water supply and distribution, wastewater collection and disposal, and stormwater drainage systems. The guidelines do not deal with other municipal infrastructures associated with parks, recreation, housing, police, fire protection, and other services.

This best practice gives municipalities guidance in support of budget requests for existing infrastructure investment through the use of relevant investment parameters. With the conviction that a strong civil infrastructure is the foundation of our society, a variety of means to protect, sustain and improve the quality of municipal infrastructure in a cost-effective manner are proposed. The scope of this document includes methodology for the development and application by municipalities of investment parameters and consideration of environmental and social factors.

Due to the uncharted identification and application of investment parameters for municipal infrastructure the full realization of this best practice's purpose faces inherent limitations. The same may be said for its scope, which is likewise circumscribed by a limited number of practices that receive application. Thus, the Decision Making and Investment Planning Technical Committee is entirely cognizant of the necessity for more research into the development of investment parameters for municipal infrastructure sought after by Canadian municipalities.

1.2 Review Methodology

The Decision Making and Investment Planning Technical Committee used the services of a consultant with an extensive background in the management of municipal government, general engineering practices, and related practical experience. The assembled team also had significant background in infrastructure-related topics.

Municipalities across Canada and internationally were contacted by e-mail and asked to complete a detailed questionnaire survey. A working group also met to review the outline of the best practice and to review pilot testing results of selected investment parameters and their application.

A literature review was conducted to incorporate relevant aspects of other formal studies. The best practice also used the personal experiences of the team members who had significant expertise in the management of these types of processes.

To protect and enhance the quality of life, the InfraGuide identifies and disseminates best practices and encourages innovation to support sustainable municipal infrastructure decisions and actions.

This guide identifies alternative best practices for a variety of situations that, in turn, will enable individual municipalities to choose the best practices that are appropriate for their organization.

1.3 How to Use This Document

This best practice has found that there are various investment techniques being used throughout the country. The outcome of this review is a mix of considerations including physical, financial, organizational, and behavioural. Many of the practices identified involve values that are difficult to measure with fixed criteria. And, as there is a wide variation among the stakeholders involved, there is a danger in trying to make one model fit all communities.

A number of factors influence this issue: data availability, political climate and budget process, and socio-economic, financial, organizational, and cultural considerations.

- Available data include accurate inventories of infrastructure covering age, materials, size, capacity, condition rating or probability of failure during a certain time frame, replacement value, and remaining value after depreciation.
- Political factors include community representation (ward basis or at large elections), the council term (very short compared to the time frame of infrastructure-related issues), the value/preferences a particular council has about capital versus operating, and elected officials' preference on block funding or project site-specific funding.
- The socio-economic factors include the community's age and its current stage in the infrastructure cycle, the mixture of residential and non-residential tax bases, and the rate of population and economic growth.
- Financial issues include competition for tax funds, the effects of downloading and general cutbacks in the government sector, the existence of dedicated funding and ownership of the various infrastructure areas, and the use of reserve funds.
- Finally, how an organization is staffed and structured, in addition to its culture, also influences the investment techniques used in a particular community.

This guide does not attempt to change the business culture of individual municipalities. Rather, it identifies alternative best practices for a variety of situations that, in turn, will enable individual municipalities to choose the best practices that are appropriate for their organization.

1.4 Glossary

Best practices — State of the art methodologies and technologies for municipal infrastructure planning, design, construction, management, assessment, maintenance and rehabilitation that consider local economic, environmental, and social factors.

Infrastructure — For the purpose of this project, the term infrastructure refers to sustainable infrastructure related to the following scope: roads & sidewalks, potable water, wastewater and stormwater.

Investment — Funds allocated to capital projects that extend the life of the existing municipal infrastructure asset base.

2. Benefits of Timely and Cost-Effective Infrastructure Investment

A wide variety of benefits result from applying the investment parameters outlined in this best practice guide in support of investment in municipal infrastructure. Much has been written on this subject. One particular organization has aptly captured some of these benefits in the following statement. The Canadian Society for Civil Engineering states:

> The asset value of Canada's infrastructure is estimated to be $1.6 trillion. Municipal infrastructure represents about 70% of the total Canadian infrastructure. Canada's municipal infrastructure debt has increased from $20 billion in 1985 to an estimated $57 billion in 2002 due to lack of long-term planning. If left unchecked, the debt could climb to more than $100 billion in 25 years. It has been shown that infrastructure owners could save as much as $1 billion per year by adopting best practices now and an additional $1 billion could be saved annually by adopting innovative practices.

2.1 Positive Impact on Taxes and User Fees

The net effect of timely investment includes reduced project costs through efficiencies of scale and avoidance of repeat repair costs. Since funding allocations are often made on overall affordability criteria, more efficient use of funding enables not only more projects, but more importantly those that are critical to be implemented, thereby reducing the infrastructure deficit and achieving higher return on investment. In the long term, cost-effective infrastructure investment will have a positive impact on taxes and user fees.

As a means of illustration, it is important to note that good roads cost less. One of the greatest benefits to adequate and timely infrastructure funding is that such a strategy yields minimal overall cost to the municipality over the long term. As a corollary, this strategy can also yield environmental benefits owing to the fact that vehicles on good roads use less fuel, good sewer systems are less likely to generate unintended releases and good water distribution systems conserve water resources.

2.2 Avoidance of Potential Risks

Failure of municipal infrastructure presents many risks to public health and safety, economic development and growth, privately and publicly owned property, the environment and to the capacity to protect the investment made in the infrastructure itself. This can include:

- Public health and safety risks of infrastructure failure including roads and bridges, water mains and sewers in addition to the social and environmental costs caused by traffic disruptions;
- Service interruption to the public;
- Water and soil contamination resulting from failed wastewater collection and disposal systems;
- Fire protection risk, industrial process interruption, other business loss, and property damage caused by water supply and distribution infrastructure failure;
- Flood damages caused by drainage system failure; and
- Risk of non-compliance with applicable legislative requirements

The above examples are by no means exhaustive, but show that timely infrastructure investment can avoid many potential risks.

It has been shown that infrastructure owners could save as much as $1 billion per year by adopting best practices now and an additional $1 billion could be saved annually by adopting innovative practices.

2.3 Effective Level of Service and Quality of Life

Healthy infrastructure provides the level of service and the quality of life Canadians deserve and demand. Deteriorating infrastructure adversely affects the level of service provided and our quality of life.

2.4 Economic Growth

Healthy and cost-effective infrastructure services aid municipalities in attracting new businesses and residents. Ailing or failed infrastructure will be detrimental in promoting economic growth and in expanding the tax base.

3. Description of Best Practices

Four best practice areas are addressed in this document; 1) an infrastructure asset reporting model; 2) high level parameters and their applications; 3) detailed level parameters and their applications; and 4) improved communication.

3.1 Infrastructure Asset Reporting Model

In Canada, there has been a move to include capital assets infrastructure in the annual financial statements for several years. In 1999, the U.S. Government Accounting Standards Board (GASB), through Statement No. 34, issued new reporting requirements for state and municipal governments resulting in those bodies now showing the value of the infrastructure assets they own (e.g., roads, bridges, water and sewer systems, drainage systems, dams and lighting systems) in their annual financial reports. While GASB regulations do not have the force of law, they establish financial reporting guidelines. Most U.S. agencies comply with GASB to avoid an adverse audit opinion on their financial statements. This is especially important to communities in the United States, where many raise money for infrastructure through bond issues. An unqualified opinion from auditors contributes to a higher bond rating, which makes it easier to raise money for infrastructure capital work through bond issues.

Canada now has the new Government Reporting Model and a new supplementary information requirements guideline for annual financial statements of federal, provincial, and municipal governments stemming from work by the Canadian Institute of Chartered Accountants (CICA). Accounting and auditing standards, including generally accepted accounting principles (GAAP) are established by a board, which is a part of the CICA.

The new reporting model for federal, provincial, and territorial governments is intended to move those bodies to full life cycle cost accounting and result in more comprehensive and useful financial statements. The new model, approved in the fall of 2002, was issued in January 2003, and will come into effect in April 2005.

It changes the treatment of capital assets (i.e., roads, bridges, water, sewer, and drainage systems, buildings, vehicles, and land) from a one time charge against annual financial results at the time of purchase or construction, to allocation of the costs of these assets over their life. This will present a more complete picture of a government's ongoing costs of providing services and will assist decision makers and the public in understanding and addressing infrastructure maintenance and replacement needs.

In September 2002, the CICA published a research report entitled *"Accounting for Infrastructure in the Public Sector."* The report looked at alternatives for accounting and financial reporting of infrastructure in Canadian governments. The study reached the following conclusions.

- Financial information about infrastructure should be provided.
- Infrastructure should be reported as an asset.
- Infrastructure acquired in lieu of developer charges or other fees, and other "acquired" infrastructure should be included in the stock of infrastructure.
- The cost of using infrastructure should be reported.
- Information about the stock of infrastructure should be accounted for on a component basis.
- Infrastructure should be depreciated over its useful life.
- At acquisition, acquired or self-constructed infrastructure should be measured at cost.
- At acquisition, "contributions" of infrastructure should be measured at estimated cost.

The new reporting model for federal, provincial, and territorial governments is intended to move those bodies to full life cycle cost accounting and result in more comprehensive and useful financial statements.

Infrastructure renewal programs must go beyond merely "catching up", they must promote long term infrastructure sustainability.

- Subsequent to acquisition, infrastructure should be measured at current depreciated reproduction cost.
- Information about infrastructure condition should be provided.
- Information related to deferred maintenance should be provided as part of the infrastructure condition information.
- Information about a government's infrastructure management plan should be provided.

The report acknowledges that, while accounting for and reporting infrastructure assets in financial statements would be a significant improvement over the current practices of many governments, other financial and non-financial information must accompany that information to promote a better understanding of the condition and needs of infrastructure.

The report further acknowledges that encouraging governments to adopt comprehensive infrastructure plans and to perform regular infrastructure condition assessments on infrastructure, will not necessarily change the decisions related to whether a government chooses to fund maintenance and replacements on a timely basis. It would, however, provide an indicator as to the effects those decisions are having on the infrastructure.

Section PS 3150 "Tangible Capital Assets" of the CICA Public Sector Accounting Handbook moves the recommendations contained in the research into the mainstream of accounting for federal, provincial, and territorial governments.

Full implementation is left to the individual government at this time as the transition provision states that governments should proceed with the adoption of these recommendations as soon as is practical, within a reasonable time period.

Many senior governments are already considering new accounting regulations, such as the CICA guidelines, for example, Ontario. It is clear the "push" in Canada for the past few years has been for annual financial statements to become more complete, and to show the real cost of government including the costs of providing, maintaining, and replacing infrastructure. In the past, the lack of information has been a major stumbling block for decision makers when it comes to infrastructure.

3.2 High Level Parameters and Their Applications

High level parameters, such as the estimated replacement cost, expected life, and condition rating classes/levels of infrastructure, can be used to establish overall annual funding requirements for infrastructure renewal programs. It is also important to note that while infrastructure renewal programs may be program specific (i.e., roads, sewer, and water) over fixed periods of time, the reality is that municipalities require both general and all inclusive renewal programs that are long term and continuous. Infrastructure renewal programs must go beyond merely "catching up", they must promote long term infrastructure sustainability.

3.2.1 Replacement Cost and Expected Life

The topic of replacement cost and expected life for municipal infrastructure is extensive. Therefore the following discussion is intended to merely provide an overview from which it is hoped the reader will refine their appreciation of the topic.

The estimated replacement cost and expected average life can be used to establish an order of magnitude for annual, infrastructure renewal, budget requirements. For example, if the estimated replacement cost of water mains in a city is $100 million and their expected average life is 100 years, then the annual budget required to sustain these water mains to their present level of service, including renewal of older water mains is $1 million (in current dollars). High level replacement costs can be estimated through consideration of the number of connections, the length of the distribution network and/or

Figure 3–1a
Age distribution of water mains in a Canadian municipality and a related future cost profile

Figure 3–1b
Future Cost Projection of Water Main Infrastructure

per capita indices. This would be the simplest approach to determine an appropriate level of investment for sustainable infrastructure. This approach will require the minimum amount of data: the total replacement cost of the infrastructure and its expected life. The replacement cost would vary with local labour, material, equipment costs and overall level of service considerations. The expected life would vary with materials, local soil, and weather conditions, and quantity and quality of demand on the infrastructure. The survey results show that municipalities use the following range of life expectancy:

Sewers	40 to 140 years
Water mains	40 to 120 years
Roads	10 to 30 years
Major structures	30 to 100 years
Equipment	10 to 20 years

Major structures associated with road, sewer, and water infrastructures include bridges, tunnels, storage tanks and basins, treatment plant buildings, dams, and dikes. Equipment associated with road, sewer, and water infrastructure includes a variety of fixed equipment among which maybe included controls, gates, and motors.

The age of infrastructure elements is not uniformly distributed due to fluctuating demand for new infrastructure over the past years, which has depended on economic and community growth. For example, a community's infrastructure could have all been built when a military base or mine was established. In such a case, most of the infrastructure investment would be required at the same time. Because of non-uniform annual infrastructure investment needs, it would be ideal to establish infrastructure renewal reserves in preparation of high demand years.

Figure 3–1a shows the age distribution of water mains and sewers in a Canadian municipality and Figure 3–1b shows a related future cost profile.

Figure 3–1a: Age distribution of water mains in a Canadian municipality and a related future cost profile

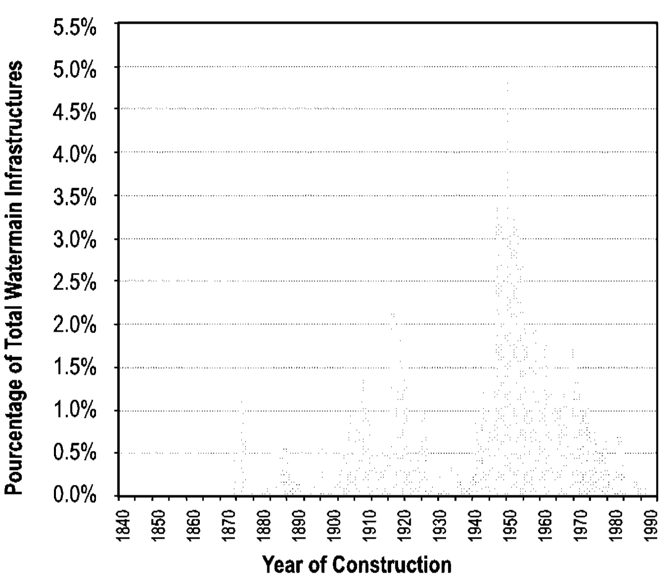


Figure 3–1b: Future Cost Projection of Water Main Infrastructure

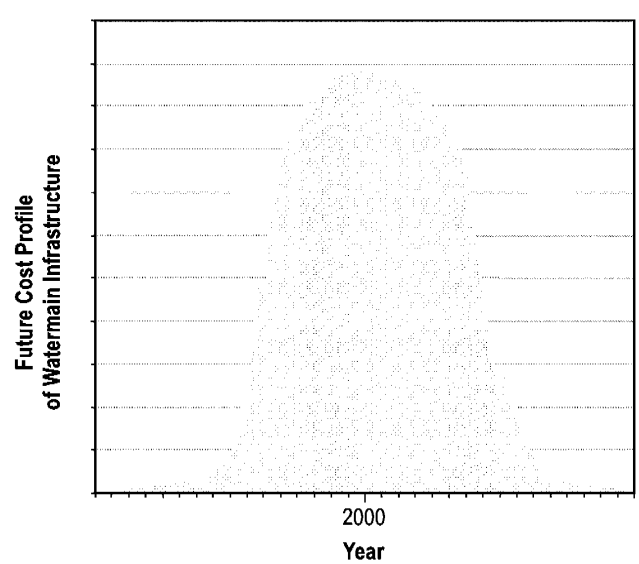


Figure 3–2
Pavement condition shift after a three-year investment program in a county in USA

3.2.2 Infrastructure Condition and Performance Rating

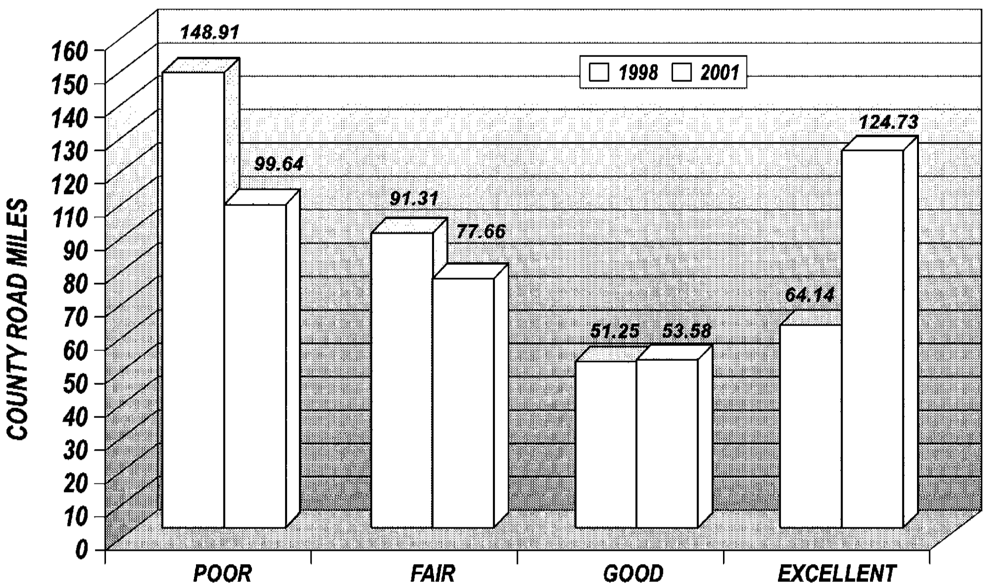
Infrastructure condition rating systems data can be used to prepare an infrastructure renewal program. Many municipalities use visual observation and/or physical measurement data to establish infrastructure condition classes or service levels and then to replace/renew the most critical class/level infrastructure. There are many rating systems used by municipalities. For example, some municipalities have adopted a four-level road condition classification system:

- Excellent condition requires no work done;
- Good condition requires pavement seal coating;
- Fair condition requires pavement overlay; or
- Poor condition requires major rehabilitation work, such as complete reconstruction.

Others use a pavement quality index (PQI) ranging from 0 (failed) to 10 (perfect condition).

As shown in Figure 3–2, one U.S. county demonstrated the shift of road condition classification inventory after a renewal program.

Figure 3–2: Pavement condition shift after a three-year investment program in a county in USA



Similarly, some municipalities use five-level sewer and manhole condition classification systems as shown in Tables 3–1 and 3–2.

Table 3–1: Sewer Rating System Example

Internal Condition Grade	Implication	Typical Defect Description
1	Acceptable structural condition	No observable structural defects.
2	Minimal collapse risk in short term but potential for further deterioration	Circumferential crack. Moderate joint defects, i.e., open joint (medium) or joint displaced (medium), spalling slight, and wear slight.
3	Collapse unlikely in near future but further deterioration likely	Fracture with deformation <5%. Longitudinal cracking or multiple cracking. Minor loss of level. More severe joint defects, i.e., open joint (large) or joint displaced (large). Spalling (medium). Wear (medium).
4	Collapse likely in foreseeable future	Broken, deformation up to 10% and broken fracture with deformation 5% to 10%. Multiple fractures. Serious loss of level. Spalling (large). Wear (large).
5	Collapsed or collapse imminent	Already collapsed. Deformation >10% and broken. Extensive areas of fabric missing. Fracture with deformation >10%.

Table 3–2: Manhole Rating System Example
Adapted from UK Water Research Center's *Sewage Rehabilitation Manual*

Internal Condition Grade	Implication	Typical Defect Description
1	Acceptable structural condition. No infiltration	No observable structural defects. No observable signs of infiltration.
2	Minimal risk of manhole failure. Minor signs of infiltration.	Minor cracks, chips, spalling. Signs of minor staining, but no visible infiltration.
3	Structural failure unlikely in near future, but further deterioration likely. Signs of infiltration.	Fracture, medium spalling, defective pipe/MH joints. Some staining, mineral buildup and seeping infiltration. Possible infiltration through manhole cover.
4	Structural failure likely in the near future. Severe signs of infiltration.	Broken manhole wall, channel, or riser assembly, multiple fractures, medium wear. Moderate staining, mineral buildup and running infiltration. Infiltration through manhole cover.
5	Structural failure or failure imminent. High infiltration rate.	Failure in manhole wall, channel, or riser assembly, multiple fractures with deformation, large wear. Heavy staining, mineral buildup and gushing infiltration. Surface ponding and infiltration through manhole cover.

Table 3–1
Sewer Rating System Example

Table 3–2
Manhole Rating System Example

3.3 Detailed Level Parameters and Their Applications

If a municipality maintains a detailed, and comprehensive infrastructure inventory database, much more accurate methods can be applied. A more detailed and comprehensive approach is to group the infrastructure into different categories based on the condition index, renewal priority index, unit cost of renewal methods and non-renewal risk index. These parameters can be used to prioritize the project items in infrastructure renewal programs.

3.3.1 Probability of Failure

Infrastructure investment decisions are often made on the basis of a condition rating system. Many municipalities use an infrastructure condition class/level system. If amunicipality has sufficient historical failure data, the probability of failure during the investment capital program period (three, five, or ten years) can be used. In such cases, the investment requirement can be estimated as the product of the probability of failure and the estimated renewal cost.

For example, a Canadian municipality in Ontario uses the probability of failure in establishing investment programs for water mains and sewers. As shown in tables 3–3 and 3–4, that particular municipality assumes that pipe failure probabilities are a function of pipe materials, size, and age. For example, 300 mm diameter original cast iron water main is assumed to have a 10 percent failure probability if it has been in service for 40 to 60 years. Accordingly, the probability of failure could be 50 and 90 percent when it reaches the age of 60 to 80 years and 80 to 100 years, respectively.

Table 3–3: Failure Probabilities Assumed by an Ontario Municipality for Water Main Age Groups in Years

Pipe Description	10%	50%	90%
Material A, ≤ 300 mm	40-60	60-80	80-100
Material B, > 300 mm and < 750 mm	50-70	70-90	90-120
Material C, 750 mm to 1350 mm	70-90	90-110	110-140
Material D, ≤ 150 mm	60-80	80-100	100-120
Material E, 200 mm to 300 mm	70-90	90-100	100-120
Material F, > 300 mm	80-90	90-110	110-130
Material G, all sizes	40-50	50-60	60-80
Material H, all sizes	45-55	55-65	65-85
Material I, 200 mm to 300 mm	40-60	50-70	60-80
Material J, original, ≥ 350 mm	50-90	90-110	110-130
Material K, all sizes	50-70	60-90	80-120
Material L, all sizes	70-100	80-120	100-150

Table 3–4: Failure Probabilities Assumed by an Ontario Municipality for Sewer Age Groups in Years

Pipe Description	10%	50%	90%
Material M, ≥ 600 mm	70-90	90-110	110-130
Material N, 750 mm to 1350 mm	90-110	110-130	130-150
Material O, ≥ 1500 mm	110-130	130-150	150-170
Material P, = 450 mm	60-80	80-100	100-120
Material Q, all sizes	70-90	90-100	100-120
Material R, all sizes (estimated)	70-90	90-100	100-120
Material S, ≤ 600 mm	60-80	80-100	100-120
Material T, 750 mm to 1350 mm	80-100	100-120	120-140
Material U, µ1500 mm	100-120	120-140	140-160

Table 3–4
Failure Probabilities Assumed by an Ontario Municipality for Sewer Age Groups

3.3.2 Infrastructure Renewal Priority Index

The infrastructure renewal priority index can be a weighted (multi-attributed) system that considers a wide range of attributes such as the service population and area, the consequences of failure, and the opportunity for a grant or being combined with other infrastructure programs. A number of well established methods such as the multi-attribute utility theory and the analytical hierarchy process or combination of both can be adapted for easy use in this environment. The weights assigned to the attributes considered in developing the priority index represents the business culture of individual municipalities and the preferences of the community it serves. When a multi-year infrastructure investment program is established, a set of priorities must be established considering the coordination of works with other infrastructure programs, their condition ratings and expected life, the risk consequences of non-renewal, expected levels of service and any funding assistance from higher level governments or developers. When one of the underground utilities is replaced, the replacement of other underground utilities and the reconstruction of roads should be considered (sometimes called "corridor renewal"). One Canadian regional district provides funding for maintaining major road networks to member municipalities only if the pavement quality index of major roads located in those municipalities exceeds 5.5 out of the perfect 10. As a result, member municipalities place high priorities on major road renewal to meet this funding condition. A substantial reduction of operation and maintenance costs resulting from infrastructure renewal should also be considered. For example, a Canadian municipality in an Atlantic province can save $250,000 a year in energy costs by replacing mercury-based street lights with a more energy-efficient lighting system. In addition, this energy saving will reduce air pollution from a local power plant, including greenhouse gas emissions. Within budget limitation, specific work must be selected from a long list of competing items. The service area and population of infrastructure may be considered in setting priorities (i.e., higher priority for major infrastructure). For example, a water supply line from a water treatment plant must have a higher renewal priority than small distribution mains.

When a multi-year infrastructure investment program is established, a set of priorities must be established considering the coordination of works with other infrastructure programs.

3.3.3 Unit Cost per Year of Extended Life

The unit cost per year of extended life can be used to determine the most cost-effective method of renewal. For example, failing sewers can be grouted, lined, or replaced at different costs, which would result in different life extensions. Sealing, patching, overlay, or reconstruction of deteriorating asphalt roads will extend the life of roads at different unit

Repair works can be an attractive option to coordinate renewal needs of one program with other programs.

costs per year of extension. One Alberta municipality reported the following information:

> Pothole repairs do not extend life, but rather attempt to maintain safety. Generally, a street that is exhibiting significant pothole development is past its serviceable life.

Maintenance paving costs approximately \$9.16 per m^2. Life extension will vary between three and fifteen years, depending on the type of work. Therefore, the annual unit cost of the maintenance paving would range between \$0.61 to \$3.05 per m^2. For example, a rut repair at a heavily used intersection may yield only three years, but a full-width pave on a collector street will likely gain 15 years. Most recent work has been in the latter category.

Microsurfacing costs approximately \$2.20 per m^2. Life extension is approximately eight years. Therefore, the annual cost is \$0.27 per m^2. This type of work is only feasible on collector and local roads.

Rehabilitation costs range from \$18.23 per m^2 for primary highways to \$34.20 per m^2 for arterials. These costs include isolated concrete work (sidewalks, curbs) and streetlights. Life extension can be as little as eight years for a concrete-based arterial resulting in an annual unit cost of \$4.28 per m^2. However, life extension can be up to 15 years for a primary highway built on a granular base resulting in a \$1.22 per m^2 annual unit cost.

Reconstruction is typically four to five times the cost of rehabilitation (i.e., \$70 to \$170 per m^2) depending on the type of road, amount of concrete work, and other conditions. Normal design life is 20 years, but local streets can last for up to 25 years. Using the normal design life of 20 years, this gives a range of the annual unit cost from \$3.50 to \$8.50 per m^2.

Similar situations exist for other infrastructures. When a municipality develops an infrastructure investment program over the programming period (three, five, or ten years), the unit cost of the rehabilitation method should be considered. In addition, social and environmental impacts of various methods should be considered (e.g., traffic interruption, air pollution, etc.). Repair works can be an attractive option to coordinate renewal needs of one program with other programs. (e.g., grouting sewer to wait for sewer renewal coinciding with road reconstruction).

3.3.4 Non-Renewal Risk Index

The infrastructure non-renewal risk index can be used to quantify the cost of failure considering the probability of failure during the renewal program. Limitations in the budget would most likely curtail the investment programs. In such cases, the consequences of non-renewal should be communicated to the senior managers, elected officials, and public.

Typical major non-renewal risks include:

- Public safety risk resulting from failure of bridges, tunnels, dams, or dikes;
- Public health risk resulting from failures of water or wastewater treatment plants;
- Property damage resulting from failed sewers and water mains; and
- Environmental/fisheries charges and fines resulting from sewerage and/or drainage system failures.

Other consequences of insufficient infrastructure investment include:

- High insurance costs due to high risk;
- Increased operation and maintenance costs resulting from frequent infrastructure repairs;
- Poor level of services affecting the citizens' quality of life; and
- Slow economic and community growth due to the difficulty in attracting new businesses and residents.
- Heightened risk of environmental degradation and associated costs.

The probability of failure and consequential cost can be presented as the expected cost of non-renewal. For example, the probability of failure for a 90-year-old high pressure cast iron water main over the next 10-year capital works program period is 90 percent, and this

1650 m water main is located in an industrial area. The probability of fire in this area is 0.0001 percent at the same time as the water main failure.

In this example, the potential cost of non-renewal may be estimated as follows.

Flood damage of basement and ground floor storage area $1,000,000 x 90 percent	$900,000
Lost business opportunity cost during damage cleanup $100,000 x 90 percent	$90,000
Road damage repair cost $17,000 x 90 percent	$15,300
Fire damage cost $200,000,000 x 90 percent x 0.0001 percent	$18,000
Therefore, the total probable cost of this particular non-renewal would be	**$1,023,300**

Similar examples can be made for standby power generation equipment failure during the power outages at a wastewater treatment plant or a water or sewage pump station.

3.3.5 An Investment Parameter Application

A particular Quebec municipality uses a "Bad Road Index" (BRI) as an investment parameter with which to establish corporate priorities while confirming its strategic plan as it relates to its infrastructure rehabilitation program. Application of the "Bad Road Index" (BRI) provides stronger and more credible justification with which to request funding from elected officials and decision makers.

For the purpose of illustration, the BRI is the percentage of road considered to be in bad and/or very bad condition. Most importantly, the acceptable threshold of the BRI is a result of local municipal considerations among which, are data collection, indicators and levels of service, and a Pavement Management System. The fact that the BRI threshold is, at least in part, dependent on the established levels of service, lends credibility as it separates the choice of specific rehabilitation efforts from less unbiased considerations. The methodology required to employ the BRI includes the following steps:

1. Data Collection (choosing indicators): A Pavement Quality Index (PQI) is established following the acquisition of data on all roads.
2. Establishing Levels of Service: Using the PQI, all roads are ranked in terms of their physical condition.
3. Investment Parameter (BRI): The percentage of roads deemed as bad or very bad is determined from the Levels of Service ranking done in step two.
4. Application: This percentage or BRI is used to identify the need to reinvest in roads.

3.4 Improved Communication

Improved communication with the elected officials and the public about the state of infrastructure and the consequences of infrastructure failure is vital in bringing about successful infrastructure investment decision making. The results of the questionnaire survey show that elected officials, senior management, and the public each use different parameters in support of infrastructure investment. Elected officials chose external funding source, impact on property taxes or user fees, and economic growth as the key parameters. For senior management, the impact on operation and maintenance, health and safety risks, and effective levels of service were priorities. The public, on the other hand, considered impact on property taxes or user fees, public health and safety risks, and effective levels of service as the top three parameters. Needs for infrastructure renewal and the consequences of non-renewal should be communicated, if

The results of the questionnaire survey show that elected officials, senior management, and the public each use different parameters in support of infrastructure investment.

possible, on the basis of the past experience and the municipality's records, and those of other municipalities. For example, a Canadian municipality started a water main renewal program in 1991 with 1.5 percent replacement per year to catch up the backlog. This was reduced to one percent replacement several years later and is now at the rate of 0.8 percent replacement. As a result of this program, water main breaks have been reduced from 70 to 55 breaks per year (about 4 breaks/100 km of pipe per year).

Optimizing communication of the costs inherent in replacing basic municipal infrastructure may be realized by relating the costs to other everyday costs. Representing infrastructure investments in relation to other elements such as hydro, cable, telephone and automobile usage can do this.

4. Limitations and Applications

The success of the various organizations in implementing the various practices outlined is subjective. Due to the differing cultural attitudes within different communities, priorities should be placed on achieving incremental improvements in the various tools used as the primary consideration. Evaluations can be made to measure a particular community against both its past practice and against the practices employed by other municipalities as outlined in this best practice guide. However, it needs to be recognized that there is a wide range of practices used and that the need for certain practices varies significantly according to the size of the community. The larger the community, the more complex the various procedures generally need to be.

Notwithstanding that many of these practices vary significantly among communities, it is possible to review the various practices outlined and periodically evaluate the success of a particular organization in implementing them. Appropriate criteria may include:

- The completeness of municipal infrastructure inventory;
- The existence of a formal asset management process, which reviews these issues;
- The size of the annual infrastructure deficit and the frequency of reporting to council and the public on these issues; and
- Funding approval procedures in the context of given election methodologies.
- Identifying and applying investment parameters in the context of municipal infrastructure engenders real challenges and limitations. Most notable among these limitations is the generally expansive and uncharted nature of relevant investment parameters. As such, the identification and application of investment parameters for municipal infrastructure is at its formative stage and in the midst of refinement and distillation.

Evaluations can be made to measure a particular community against both its past practice and against the practices employed by other municipalities as outlined in this best practice guide.

5. Needs for Further Research

The needs for further advancement in the following areas have been identified:

- Development of non-invasive, non-destructive technologies and methods for evaluating and assessing the condition of municipal infrastructure systems in a timely and cost-efficient manner;
- Development of deterioration models for individual infrastructure assets to facilitate the estimation of the remaining expected life of these assets;
- Development of easy to use, domain specific, and multi-attributed decision support systems to assist in establishing priority rankings at strategic and tactical levels, capable of addressing integration issues in the planning renewal programs;
- Development of a more systematic and structured method of evaluating social/environmental costs;
- Development of a critical funding model which integrates the various utility management systems with the funding capabilities of particular municipalities;
- Establishment of dedicated funding sources for all infrastructure areas including roads;
- Development of an infrastructure failure risk assessment model;
- Research into asset life expectancies;
- Forecasting tools that will improve the ability to gauge the life cycle of various buried pipe infrastructures, thereby yielding more accurate predictions of the probability of their failure; and
- Expanding on the material presented here on investment parameters and their applications relative to municipal infrastructure, including the development and testing of applicable parameters and models.

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Notes