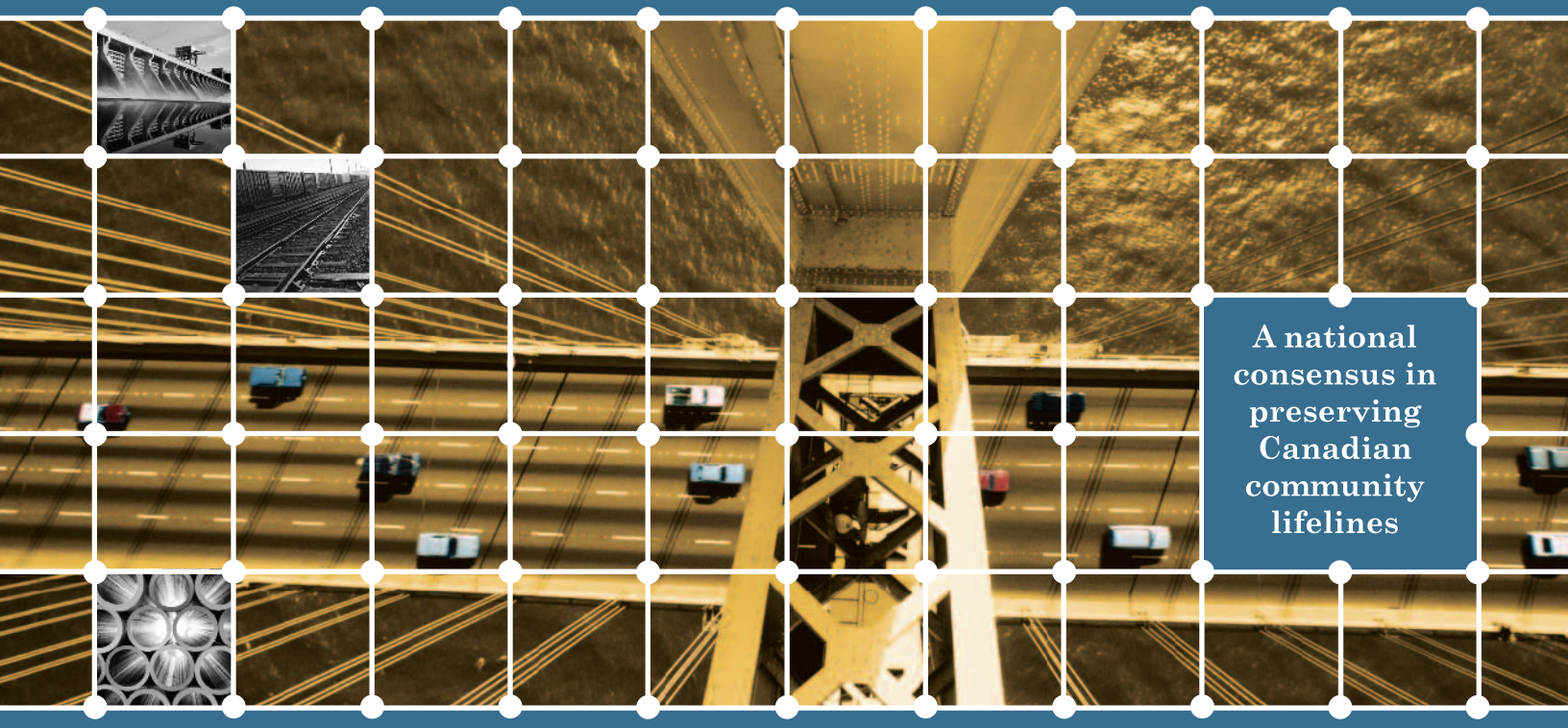
Civil Infrastructure Systems

Technology Road Map

2003-2013



A national consensus in preserving Canadian community lifelines

☐ INDUSTRY ☐ INFORMATION ☐ INVESTMENT ☐ INNOVATION

Civil Infrastructure Systems Technology Road Map
2003–2013

A national consensus on preserving
Canadian community lifelines

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Acknowledgements

The Canadian Society for Civil Engineering, the Canadian Council of Professional Engineers, the Canadian Public Works Association and the National Research Council of Canada wish to express their appreciation to all those who, through their generous contributions of time and energy, assisted in producing this report.

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We appreciate the contributions of the Town Hall Meeting participants. Their names and affiliations are provided in the Appendix.

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We appreciate the contributions from the individuals who provided comments, photographs and assistance in organizing and circulating information on TRM events. Their names and affiliations are provided in the Appendix.

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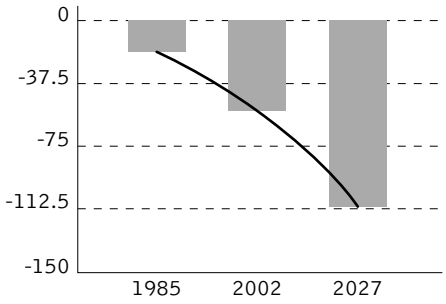
We extend our special thanks to Guy Félio of the National Research Council of Canada for his expertise and guidance throughout the Technology Road Map development process. This report would not have been completed without his outstanding contribution.

Executive Summary

The State of Canada's Infrastructure

How much infrastructure backlog are we accumulating? ($ Billions)



The value of Canada's civil infrastructure systems (CIS) lies in their delivery of the essential services that provide the foundation upon which healthy, prosperous and safe communities are built. However, Canada's CIS — highways, roads and airports, as well as systems for water supply, storm water management and waste water treatment — are deteriorating.

The Need for Action

Failure to address this deterioration will lead to increasing maintenance and repair costs, along with reduced levels of service that may threaten public health, the environment and the economic prosperity of our communities. The CIS community has reacted to this pressing need by developing a strategy that will guide the rehabilitation, replacement and future development of Canada's CIS. A Technology Road Map (TRM) was identified as the first step in mobilizing the industry for this strategy.

We are inviting the governments of Canada to join the CIS community in developing and implementing a long-term National Infrastructure Action Plan that addresses the challenges faced by our current infrastructure systems.

As we work together, our strategy will result in a strong, efficient, above- and below-ground infrastructure that will reduce our vulnerability from an economic and competitiveness perspective, create wealth and jobs and ensure the health and safety of all Canadians.

Modern transportation linkages resulting in prosperous and vibrant communities

Development of the Technology Road Map

The TRM represents a national consensus on the current state of infrastructure systems, a vision for the industry and a strategy for meeting the long-term needs of Canada's CIS through technology innovation. The preparation of the TRM was led by four national bodies: the Canadian Society for Civil Engineering, the Canadian Council of Professional Engineers, the Canadian Public Works Association and the National Research Council of Canada.

Early in the TRM process, the following goals were identified:

- To promote and build support for an ongoing, long-term, holistic investment in the innovative technologies needed to renew and enhance Canada's CIS;
- To adopt the TRM as a blueprint for the renewal and enhancement of Canada's CIS;
- To develop a nationally shared vision among all partners;
- To develop a realistic and exhaustive analysis of the state of CIS, as driven by the construction industry needs; and to increase research and development.

More than 140 leaders and experts were consulted in Canada-wide Town Hall Meetings. These consultations resulted in a list of 10 Technology Road Map objectives for the next decade. A set of key recommendations for meeting these objectives was also developed to encourage CIS industry stakeholders to take immediate action.

Participants also identified several important issues that are not directly associated with technology. These non-technology issues are related to policy and standards, to legislative framework and to resources. Because technology issues cannot be dealt with in isolation, these non-technological issues must still be accounted for in stakeholders' action plans.

The Vision of the Technology Road Map

The TRM identifies the challenges and the associated technological needs that will influence the infrastructure industry during the next 10 years. Its goal is to facilitate the introduction of new technologies and improved management practices that will ensure the sustained prosperity of Canadian communities. The TRM extends an *invitation to action* to all CIS stakeholders to work together to achieve this goal.

Technology Road Map Objectives

The 10 interrelated objectives are the essence of the Technology Road Map (TRM). The 10 objectives are listed below.

- **Asset Inventory and Condition**

  To develop a reliable and accessible inventory of Canada's infrastructure, including location, condition and valuation that supports integrated asset management.

- **Benefits of Maintenance and Rehabilitation**

  To develop an accurate understanding of the relationship of proper maintenance and rehabilitation practices to the life expectancy of infrastructure.

- **Life-Cycle Cost/Benefit Analyses**

  To integrate technical, economic, environmental and social factors into sustainable CIS investment decision-making processes that are based on life-cycle cost/benefit analyses.

- **Integration of Civil Infrastructure Systems**

  To manage the infrastructure as a system of interdependent assets.

- **Technology Evaluation**

  To develop tools to evaluate the field performance of existing infrastructure systems and to predict the performance of new technologies and materials.

- **Knowledge Management**

  To implement processes to properly manage and share knowledge.

- **Diverse and Adaptable Technology**

  To increase the diversity of and access to technologies for the design, construction, maintenance and rehabilitation of infrastructure, adapted to local conditions.

- **Monitoring and Control Operations**

  To implement technologies to optimize the operation and maintenance of infrastructure through real-time monitoring and control.

- **Quality Assurance and Quality Control**

  To expand the use of tools and processes to improve the quality of design, construction, rehabilitation, management and operation of infrastructure systems.

- **Education, Training and Outreach**

  To ensure that educational, training and public outreach programs meet the needs of decision makers, the workforce and the industry.

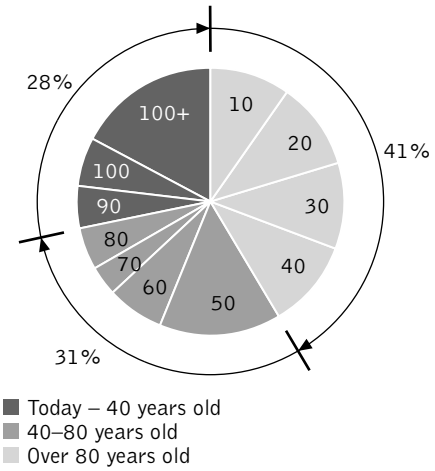
Recommendations for Action

The key enabling recommendations, related to the 10 objectives, provide a catalyst that will stimulate activities throughout the CIS community. These activities are intended to accelerate the development of new and innovative processes and technologies.

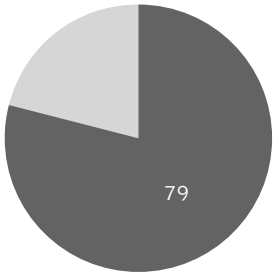
The recommendations are:

- **To request that the federal government create a National Round Table for Infrastructure (NRTI), bringing together all stakeholders to develop a National Infrastructure Action Plan.** ***An expert advisory body of the NRTI will advise on technology issues.***
- **To develop a cost-effective mechanism by which data on infrastructure inventory and condition assessment are collected from municipalities and from other infrastructure owners as they apply for Infrastructure Canada and other funding.**
- **To include life-cycle analysis in the selection of CIS projects or technologies submitted by and to municipalities.**
- **To request that Infrastructure Canada establish a national innovative-technologies demonstration program.**
- **To establish a Network of Centres of Excellence, or an equivalent, for infrastructure.**
- **To request the federal, provincial, territorial and municipal governments and industry partners to dedicate funds to infrastructure research and development.**
- **To integrate infrastructure rehabilitation and maintenance content into curricula and into continuing education programs.**
- **To establish an infrastructure technology transfer program to encourage the movement of technology from research facilities to the marketplace.**
- **That within five years, the progress and success of the TRM be measured in relation to its objectives and that the TRM be revised and updated as necessary.**
- **That the partnership of professional organizations that led the TRM and the members of the Expert Panel offer their expertise to organizations that adopt the recommendations, with the goal of helping them achieve the TRM objectives.**

How old is our infrastructure? (years)



How much of our infrastructure's life expectancy have we used? (%)



An Invitation to Action

The Message from the Chair

Reg Andres, PEng
Chair of the CIS-TRM Expert Panel and Vice-President of R.V. Anderson Associates Limited

Public health, environmental protection and economic prosperity are crucial to nurturing vibrant Canadian communities, the building blocks of a successful nation. The viability of these communities relies on a healthy and durable infrastructure that can deliver the essential services associated with fresh water, waste water and transportation.

But the existing infrastructure systems, on which these services rely, are aging rapidly at a time when many communities are growing. These systems have reached a critical stage in their history and are challenging Canada's civil infrastructure systems (CIS) industry with unprecedented levels of decision-making, intervention and investment.

Canada's CIS represents a $25 billion annual industry. The diversity and complexity of its components and stakeholders present a significant challenge to finding a common vision and an integrated approach to industry needs. There are more than 3,000 CIS owners under federal, provincial, territorial and municipal jurisdictions across Canada, serving customer bases ranging in size from a few people to several million. In addition to owners, the CIS industry includes the engineering profession and many organizations representing a variety of industry interests, including those of contractors, builders, policy makers, researchers and academics. All are stakeholders with individual and specific mandates.

The diversified infrastructure industry, supported and guided by a partnership of national professional associations, undertook the challenge of developing a national consensus that would identify needs and a strategy to meet the challenges of Canada's CIS. The result was the infrastructure Technology Road Map (TRM), developed as a blueprint for technological innovation for the entire CIS industry. Ten objectives were established for the next 10 years, using input from more than 140 Canadian industry leaders and experts to address the long-term management issues of Canada's CIS.

The TRM is an invitation to action for the CIS community. Senior government agencies, municipalities, consultants, contractors, research organizations, academic institutions and professional associations — all of whom have an interest in civil infrastructure systems — are challenged to review this document and:

- adopt the TRM objectives as the national vision for the long-term management of the CIS;
- within the mandate of their organizations, develop an action plan that will achieve the TRM objectives, and
- if necessary and possible, expand the mandate of their organizations to create the opportunities necessary to meet the objectives of the TRM.

The challenge facing Canada's CIS is significant. It requires a national action plan and a common national vision. Collectively, the CIS industry has the potential and the capability for making a positive impact on the future. You are invited and encouraged to become a leader in developing the solutions that our community needs.

Reg Andres, PEng
Chair of the CIS-TRM Expert Panel and
Vice-President of R.V. Anderson Associates Limited

Improving the efficiency and convenience of our transportation structures

The State of Canada's Civil Infrastructure Systems (CIS)

Making use of innovative geotextile water covers

Every Canadian community stands on a foundation that is only partly visible to its citizens. But visible or not, this foundation is vital to the health, well-being and prosperity of everyone in the country. It is composed of highways, airports, water-treatment plants, culverts, causeways and roads. It is the infrastructure of the country and, if it did not exist, Canada would not exist, either — at least not the Canada we know. Without this foundation, our water would be unsafe, our journeys slow and our economy stagnant. The prosperity we have achieved would have been an impossible dream.

A great deal of this prosperity has come since 1945, during the great urban expansion that followed World War II. This prosperity depends upon an infrastructure that is now aging. Some of this infrastructure has already reached the end of its service life and is breaking down. Many of the remaining systems will need renewal or replacement within the next 10 years. If we do not begin to rehabilitate and rebuild our CIS, our cities and economy will be stifled by an inadequate and obsolete infrastructure. The resulting unreliable services, increased congestion, decaying physical environments and financial stresses will severely affect Canadians' quality of life.

Few experts disagree that investments in CIS, such as water-treatment facilities, roads and bridges pay great dividends to public health, the environment and the economy. However, Canada's CIS has been deteriorating rapidly. In 1985 it was estimated that the cost to rehabilitate just the municipal infrastructure, which represents only 70 percent of the total Canadian CIS,

would exceed $20 billion. Despite the additional investments of recent years, this municipal backlog has risen to an estimated $57 billion. If left unchecked, the amount could climb to more than $110 billion by 2027.

The decay of the infrastructure creates severe domino effects. Among these are:

- higher costs of maintenance, rehabilitation and repair;
- inefficiency and increased vulnerability of our systems; and
- threats to public safety.

Current expenditures on design and construction of infrastructure are significant, being estimated at 30 to 40 percent of Canada's total construction activities.

Infrastructure building blocks

The federal government is aware of the need for action, as it demonstrated by establishing the Infrastructure Canada Program in 2000. The need to disseminate and share knowledge led to *The National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices*, a project funded under the Infrastructure Canada Program and implemented by the Federation of Canadian Municipalities in partnership with the National Research Council of Canada.

In 2002, the Department of Infrastructure Canada was established to provide a focal point for Government of Canada leadership on infrastructure issues. Infrastructure Canada funds specific projects and provides strategic advice and policy direction in a 10-year program that addresses long-term, strategic infrastructure-related initiatives.

In February 2003, Transport Canada launched *Straight Ahead — A Vision for Transportation in Canada*. This document cites the need for strategic infrastructure investments during the next decade to support the government agenda for competitive communities, for management of climate change and for encouraging innovation.

Finally, in the context of the National Innovation Strategy launched by the Government of Canada in early 2002, the CIS industry came together and, under the leadership of four national organizations, created a Technology Road Map (TRM). The TRM identifies the technology needs and challenges of the CIS industry for the next 10 years and makes the recommendations necessary for meeting them.

Municipalities keeping their pace on roads and sidewalks

The Technology Road Map: Paths to Innovation

The TRM, which is the blueprint toward adopting innovations in CIS technologies, identifies the interrelationships among the components of the CIS industry and provides a basis for action plans to achieve its goals. The TRM represents the industry's consensus on:

- a vision for the industry's future;
- the maintenance and rehabilitation of existing infrastructure;
- the new products and services required;
- the technologies to create these products and to provide these services;
- the feasibility of creating these technologies; and
- how technological challenges can be addressed through research and development.

The TRM project began in 2002 with a background study that supported a series of Canada-wide Town Hall Meetings. Owners, end-users, operators, consultants, manufacturers, suppliers, contractors and the scientific community have participated in the TRM process, which has been both consultative and inclusive. The aim of the TRM is to encourage stakeholder organizations to develop science and technology action plans for the construction, rehabilitation and management of our CIS. These plans will maximize the benefits of Canadian investments and will bring the Canadian construction industry to the forefront, both domestically and internationally.

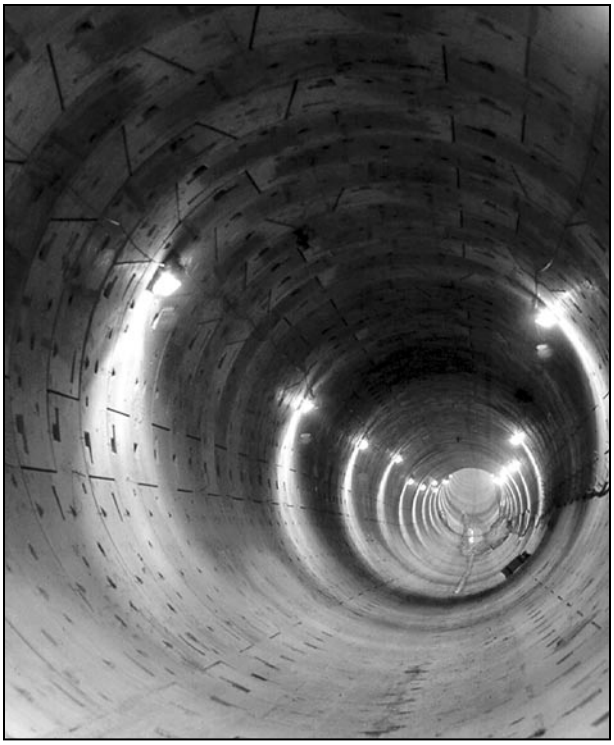
Early in the TRM process, the following goals were identified:

- to promote and build support for an ongoing, long-term, holistic investment in the innovative technologies needed to renew and enhance Canada's CIS;
- to adopt the TRM as a blueprint for the renewal and enhancement of Canada's CIS;
- to develop a nationally shared vision among all partners;
- to develop a realistic and exhaustive analysis of the state of CIS, as driven by the construction industry's needs; and
- to increase research and development.

Four organizations led this project to ensure the rapid, effective development and management of the TRM: the Canadian Society for Civil Engineering (CSCE), the Canadian Council of Professional Engineers (CCPE), the Canadian Public Works Association (CPWA) and the National Research Council of Canada (NRC). These organizations represent a wide range of disciplines within the CIS community.

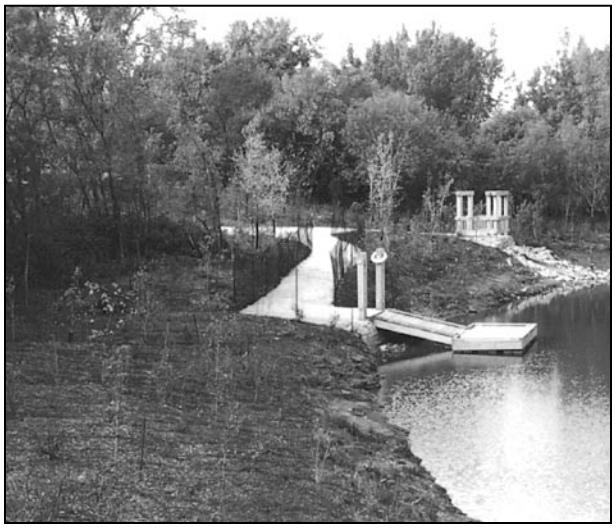
Numerous other organizations and associations have been involved in acquiring and distributing the information required to complete the TRM by June 2003. Among these participants were:

- federal and provincial governments;
- municipalities;
- owners and operators;
- consulting engineers;
- construction companies;
- manufacturers;
- suppliers; and
- universities and colleges.



Ground-breaking technology in our subway systems

Organizational Structure of the Technology Road Map Project



Preserving the environment

The TRM project was overseen by a Project Steering Committee. This committee created an Expert Panel, chaired by Mr. Reg Andres, Vice-President of R.V. Anderson Associates Ltd., composed of recognized researchers and practitioners from across Canada.

The TRM Project Team

CIS-TRM Project Steering Committee:

Co-Chair	Sherif Barakat	National Research Council of Canada
Co-Chair	Gordon Jin	Canadian Society for Civil Engineering
	Marie Lemay	Canadian Council of Professional Engineers
	Wally Wells	Canadian Public Works Association
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	Dave Rudberg	City of Vancouver
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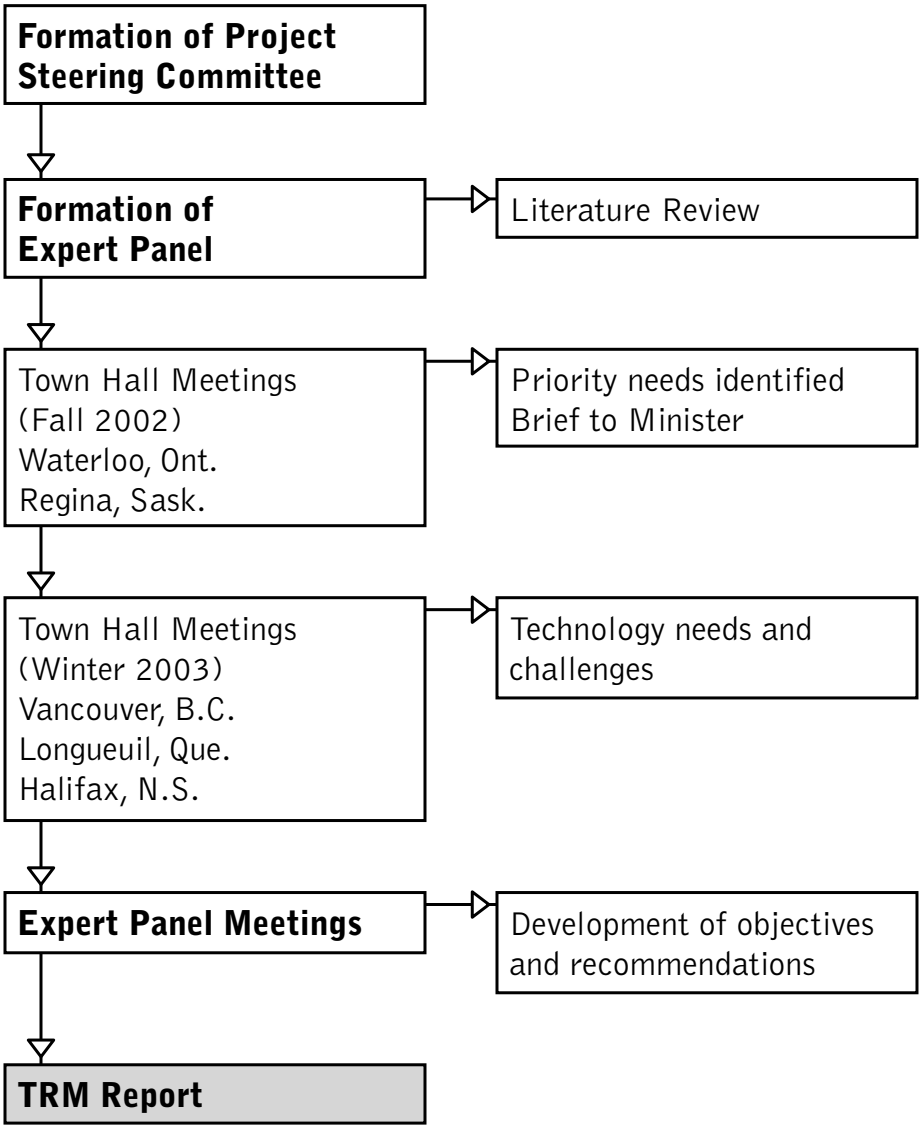
	Don A. Taylor	National Research Council of Canada

Stakeholders
Industry, Academia, Government,
Trade and Professional Associations

Development of the TRM Process



Consultations: The Town Hall Meetings

Field consultations in the TRM process were undertaken as regional Town Hall Meetings. Dr. Ian Moore of Queen's University reviewed current literature and summarized various major infrastructure studies undertaken since 1985. This document was used as a reference by attendees at the September 2002 Town Hall Meetings.

Keeping our waters clean through sustainable environmental initiatives

Town Hall Meetings: Waterloo and Regina

The objectives of these two meetings were to:

- articulate a vision;
- define and validate directions to consider over the next 10 years;
- define and validate gaps in technology development and applications; and
- prepare a list of research needs for new products, materials and services during the next 10 years.

At each meeting there were approximately 30 participants, representing a wide range of disciplines and interests, who exchanged views on the needs of CIS during the next decade.

Brief to the Minister

Based on the deliberations of the first two Town Hall Meetings, a brief entitled *Critical Condition: Canada's Infrastructure at the Crossroads* was prepared and submitted to the Deputy Minister of the Department of Infrastructure Canada. This brief provided input to the Government of Canada's Innovation Strategy consultations during the summer and fall of 2002.

Town Hall Meetings: Vancouver, Longueuil and Halifax

In early 2003, three more Town Hall Meetings were held in Vancouver, British Columbia; Longueuil, Quebec; and Halifax, Nova Scotia. The focus of these meetings was to build on the results of the Waterloo and Regina meetings and to define:

- the technology development needs of CIS during the next decade; and
- the technology challenges to Canadian CIS.

General Conclusions and Recommendations of the Town Hall Meetings

Following the Town Hall Meetings, the Expert Panel, through a series of working sessions, reviewed the results, drafted specific objectives, identified associated challenges and technology needs, and prepared a number of enabling recommendations.

Innovative ground-breaking techniques in construction.

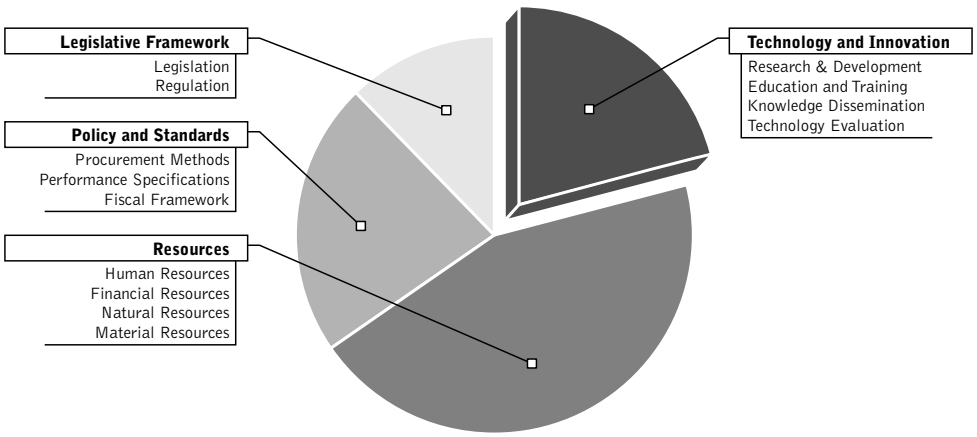
Canada's Infrastructure Needs:
Key Elements of a National Infrastructure Framework

The five Town Hall Meetings identified several important issues not directly associated with technology: policy and standards, legislative framework, and resources. Combining these issues with the issues considered by the TRM establishes a framework for a national policy that can respond to Canada's infrastructure needs. These non-technical issues are described below so that stakeholders can account for them in their action plans. Technology could also support actions in these domains. This list is not exhaustive but can lead to future discussions.

Policy and Standards

Policy and standards include performance specifications, procurement and fiscal framework. One key issue relates to present procurement practices, typically prescriptive and based on

Key Elements of a National Infrastructure Framework



lowest initial cost. These practices are viewed as significant barriers to innovation and as the cause of reduced service lives and sub-optimum investment returns. Solutions to changing the present procurement philosophy include performance-based specifications and life-cycle cost accounting.

Another major concern of the Town Hall Meetings is the valuation and reporting/accounting of infrastructure assets. Although several initiatives across Canada and the U.S. are addressing this, numerous issues remain, such as how to quantify and integrate the engineering, social and environmental values of the assets, the total and residual life of the infrastructure and how the asset value is reported and to whom. Solutions to these issues should lead to uniform/standardized methods of economic analysis.

Legislative Framework

The CIS community feels that several policies and standards issues, including asset valuation, accounting, reporting and life-cycle costing, should be legislated.

Finally, because infrastructure systems are crucial to the safety and the economic and social well being of Canadians, the TRM participants support legislation to require the certification of operators of critical systems.

Resources

The infrastructure industry is a resource-intensive sector that requires financial, human, natural and material resources. Funding infrastructure remains a great concern for the industry. The TRM participants recommend mandated organizations at all levels of government to explore and establish innovative funding mechanisms, and to include private sector stakeholders in this approach. Subjects retained under funding mechanisms include:

- developing and implementing user-pay technologies;
- basing decisions on life-cycle costs and benefits;
- using full-cost accounting;
- making decisions according to sound demand-management analyses; and
- developing and sharing innovative funding mechanisms, possibly with legislative changes to allow more private sector participation.

Several issues relating to highly qualified labour and skills were retained as critical to CIS. These include education programs at all levels, succession planning, accreditation/certification programs, collaborations between labour training organizations and the industry, and work-based education such as co-op programs at universities and colleges.

It is important to address the non-technology issues raised by the development of the TRM. It is recommended that a National Round Table for Infrastructure be created so that stakeholders can more effectively cooperate in developing recommendations for action on policy and standards issues, legislative and resources issues.

Objectives

From the consultations of the five Town Hall Meetings involving over 140 individuals, objectives for Canada's CIS were formulated for the next decade. In addition, recommendations for immediate action to achieve the stated objectives were developed. The 10 objectives are:

- **Asset Inventory and Condition**

  To develop a reliable and accessible inventory of Canada's infrastructure, including location, condition and valuation, that supports integrated asset management.

- **Benefits of Maintenance and Rehabilitation**

  To develop an accurate understanding of the relationship of proper maintenance and rehabilitation practices to the life expectancy of infrastructure.

- **Life-Cycle Cost/Benefit Analyses**

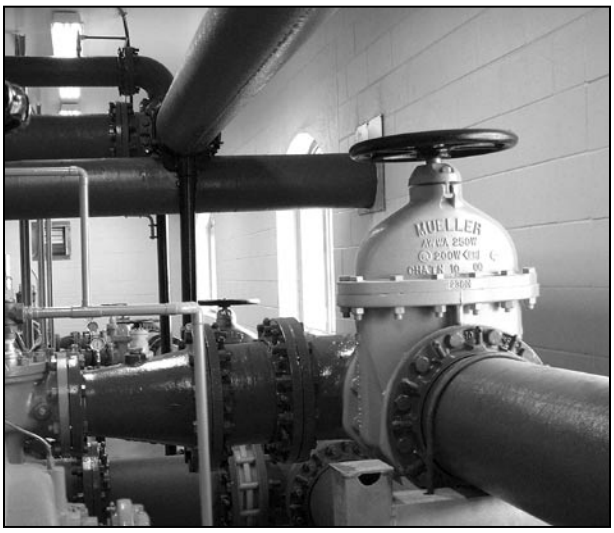
  To integrate technical, economic, environmental and social factors into sustainable CIS investment decision-making processes that are based on life-cycle cost/benefit analyses.

- **Integration of Civil Infrastructure Systems**

  To manage infrastructure as a system of interdependent assets.

- **Technology Evaluation**

  To develop tools to evaluate the field performance of existing infrastructure systems and to predict the performance of new technologies and materials.



Maintaining our water-treatment plants

- **Knowledge Management**

  To implement processes to properly manage and share knowledge.

- **Diverse and Adaptable Technology**

  To increase the diversity of and access to technologies for the design, construction, maintenance and rehabilitation of infrastructure, adapted to local conditions.

- **Monitoring and Control Operations**

  To implement technologies to optimize the operation and maintenance of infrastructure through real-time monitoring and control.

- **Quality Assurance and Quality Control**

  To expand the use of tools and processes to improve the quality of design, construction, rehabilitation, management and operation of infrastructure systems.

- **Education, Training and Outreach**

  To ensure that educational, training and public outreach programs meet the needs of decision makers, the workforce and the industry.

The Technology Road Map

The Technology Road Map for Canada's CIS is an invitation to action for the infrastructure industry. All parties with an interest in civil infrastructure systems are challenged to review the objectives and recommendations of the Road Map and:

- adopt the TRM objectives as a national vision for the long-term management of CIS;
- within the mandate of their organizations, develop an action plan that will achieve the TRM objectives, and
- if necessary and possible, expand the mandate of their organizations to create the opportunities necessary to meeting the objectives of the TRM.

In the context of the TRM, civil infrastructure systems have been limited to:

- transportation structures, including roads, bridges, sidewalks and airports, but not transportation fleets; and
- environmental structures, including drinking water, storm water and waste water systems, but not gas and power utility systems.

Inspection and management of our infrastructure

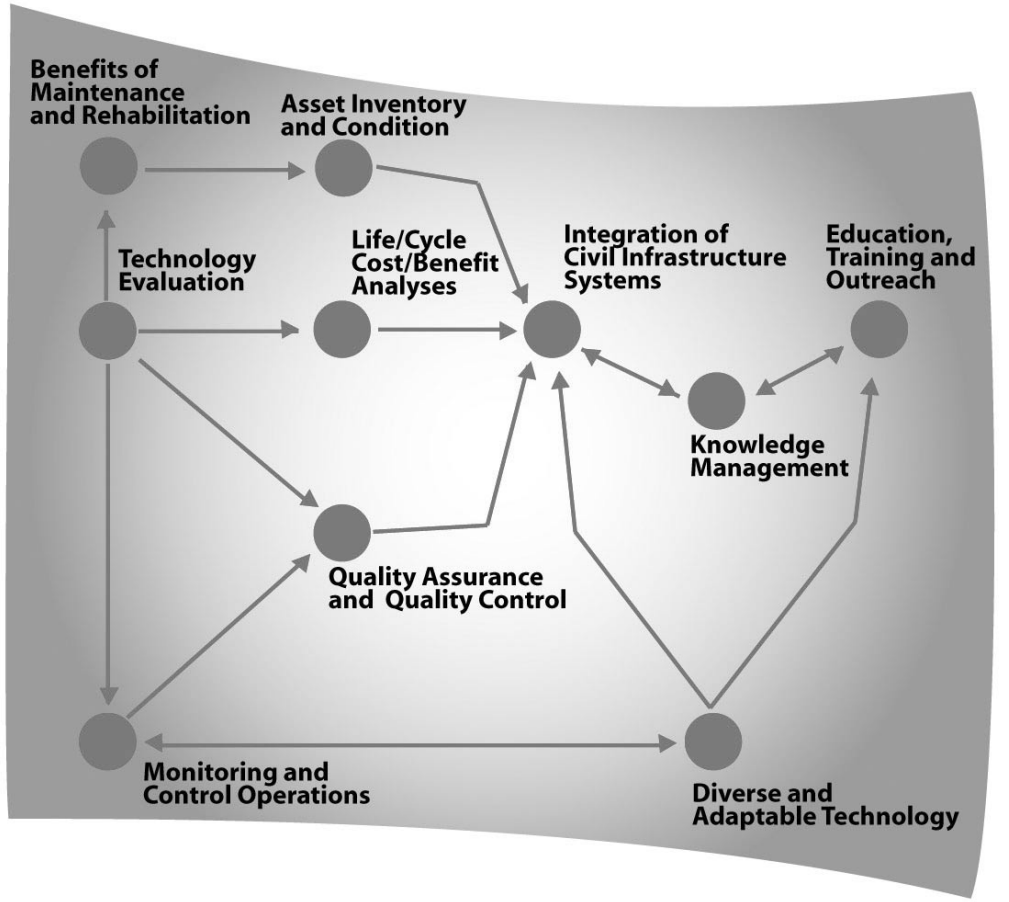
Using the Technology Road Map

The TRM speaks to federal, provincial, territorial and municipal governments, and to manufacturers, suppliers, consulting engineers, construction companies, associations, researchers, educators and the public. The TRM makes it possible to understand and seize the opportunities and challenges of the Canadian CIS and provides a tool that will help all parties plan their activities and establish their priorities and strategies.

Each of the 10 objectives is presented in the following pages. With each presentation is a graphical version of the TRM, a statement of the particular objective and a table of the major challenges and technology needs associated with it. The graphical version of the TRM allows the reader to identify the coordinates of the objective within it. To understand the interrelationships illustrated by the TRM, it is necessary to study the TRM, its individual objectives and their interrelationships in an iterative process.

The linked objectives, major challenges and technology needs define what is required to achieve specific objectives.

Technology Road Map

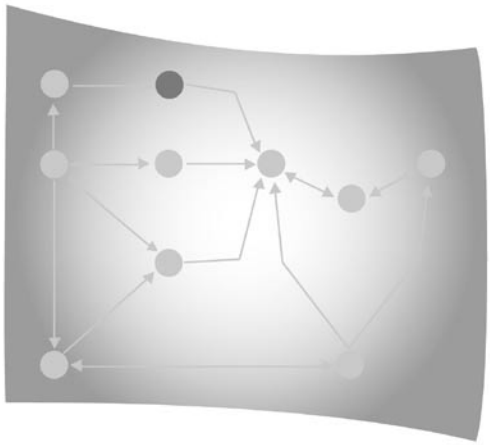


Asset Inventory and Condition

To develop a reliable and accessible inventory of Canada's infrastructure, including location, condition and valuation, that supports integrated asset management.

Canadian municipalities, owners and operators currently have tools such as Global Positioning Systems (GPS) and Geographical Information Systems (GIS). They will be encouraged during the next decade to develop an integrated infrastructure inventory that supports the planning of interventions and investments in CIS and assists all levels of government in planning policies and programs.

Asset Inventory and Condition	
Major Challenges	**Technology Needs**
• A wide range of infrastructure networks are owned and managed by a variety of different entities. • Physical access to CIS can be difficult, for example, to underground systems, or to systems without redundancy that are in constant use. • Existing condition assessment technologies are not well developed, are not easily accessible, are often too costly and are seldom used. • Data collection, management and long-term maintenance often require human, financial and technological resources that are beyond the reach of many CIS owners. • Knowledge of CIS condition is not viewed as a good investment; occasionally, knowledge of the state of CIS is interpreted as a liability. • Currently it is difficult to relate knowledge of CIS condition to investment needs.	• Non-destructive, non-invasive technologies for the inspection of above- and below-ground infrastructure • Methods for accurately locating existing infrastructure • Accepted methods and tools for the valuation of CIS assets • Development and maintenance of a national inventory of infrastructure, including geographic location • New technologies for the analysis of system components or of the system as a whole • Methodologies to determine which components require inspection, and to establish frequency of inspection • Uniform/common condition indicators and rating systems that can be used in prediction models, asset-management systems and decision-making processes • Sensor and associated communications and analysis systems for real-time monitoring of infrastructure condition • Deterioration models



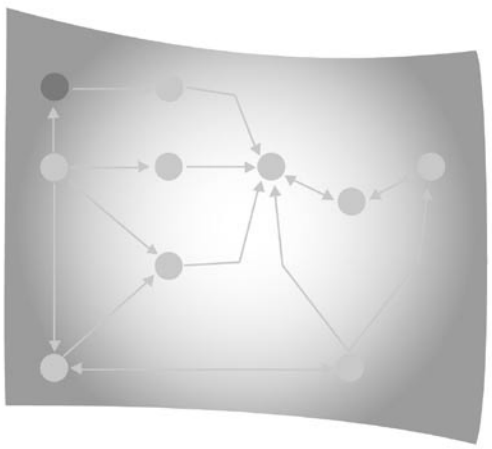
Benefits of Maintenance and Rehabilitation

To develop an accurate understanding of the relationship of proper maintenance and rehabilitation practices to the life expectancy of infrastructure.

In the next decade, Canadian municipalities and CIS, owners and operators will have access to improved practices and strategies for the maintenance and rehabilitation of their infrastructure. The benefit will be the extension of the useful life of CIS. In addition, a better understanding of the factors affecting service life will improve the ability of owners and operators to evaluate new technologies for the renewal and rehabilitation of their infrastructure assets.

Benefits of Maintenance and Rehabilitation	
Major Challenges	**Technology Needs**

• Service life of infrastructure is affected by many factors over a long time span, complicating an economic analysis. Factors include:
  • materials;
  • installation procedures;
  • environment;
  • maintenance; and
  • service loads.
• CIS are often difficult to inspect due to access problems and continuous utilization.
• Management and rehabilitation practices vary greatly among CIS owners and operators.
• There is a lack of historical performance data for underground systems, and there are problems with predictive model validation.
• Performance indicators for determining the condition of CIS are not widely available, and when they exist are seldom used.
	• Identify and characterize the key factors that influence the longevity of infrastructure, including:
	  • quantification of improvements due to interventions such as repair, maintenance and rehabilitation; and
	  • acceleration of deterioration due to breaks or failures.
	• Predictive models for the residual life of infrastructure that support asset management and decision-making
	• Performance indicators that are relevant, reliable, easy to measure and widely used

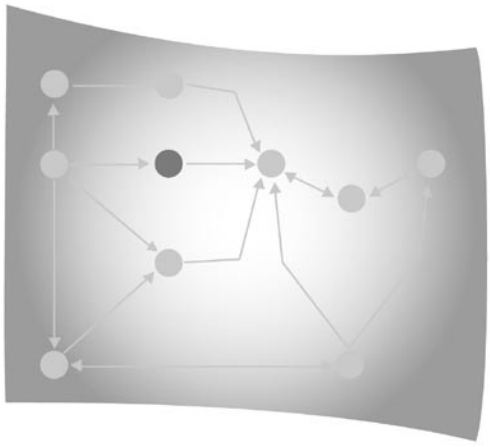


Life-Cycle Cost/Benefit Analyses

To integrate technical, economic, environmental and social factors into sustainable CIS investment decision-making processes that are based on life-cycle cost/benefit analyses.

In the next decade, municipalities and other CIS owners will have methods of integrating technical and financial information, as well as life-cycle cost/benefit analyses, into their decision-making processes and sustainable asset-management programs. The environmental and socioeconomic costs, and benefits of infrastructure projects, should be quantified over the life cycle of the assets.

Life-Cycle Cost/Benefit Analyses	
Major Challenges	**Technology Needs**
• Costs vary over the life of the infrastructure, depending on the level of service and utilization. • Most procurement systems are not conducive to life-cycle costing. • Benefits of life-cycle costing are not well understood by administrators and decision-makers. • Environmental and social costs are intangible and difficult to estimate. • Decision-makers' concerns are often short-term, while infrastructure investments require long-term commitments and planning.	• Identify and characterize life-cycle costs (economic, environmental and social) and evaluate the factors that influence these and associated costs, including the effects of demand, service and load levels • Develop models for the life-cycle costs of infrastructure that are adaptable to wide-ranging conditions and can be incorporated into asset-management and decision-making systems • Create tools to determine the factors that influence the service life of assets • Develop methodologies to incorporate life-cycle costs into procurement systems and procedures

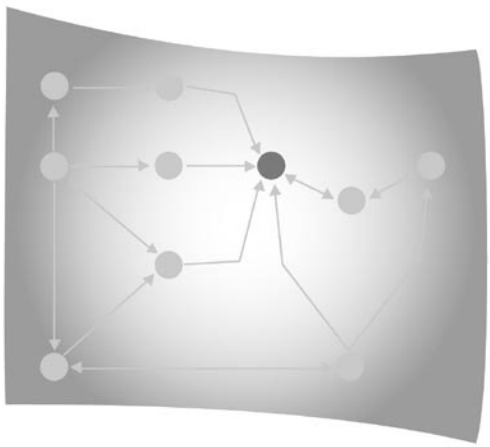


Integration of Civil Infrastructure Systems

To manage infrastructure as a system of interdependent assets.

In the next decade, municipalities and other CIS owners will have the tools for an integrated system of asset management for all infrastructure systems. This will simplify the coordination of interrelated work, decrease disruptions of service and traffic, and extend the service life of CIS components. It will also lead to more efficient management, increased safety and more effective transfer of information and knowledge.

Integration of Civil Infrastructure Systems	
Major Challenges	**Technology Needs**
• There is a lack of collaboration and coordination within and among utilities. • Decision-making models do not account for interrelations or interdependencies. • Critical components of networks and systems are ill-defined. • Investments are most commonly made on the basis of individual problems or components, without a full evaluation of the entire network or system. • Infrastructure asset-management systems are not widely used, particularly by small municipalities.	• Data-collection methods and data standards that facilitate integration among a wide range of CIS • Performance indicators and benchmarking tools that allow cross-systems evaluation and comparison • Tools to evaluate the critical components of CIS that need to be integrated into a holistic system • Mechanisms for shared accessibility to information on CIS • Infrastructure management systems adaptable to the complexity of the infrastructure under consideration, such as simple systems for small municipalities • Tools to evaluate the interdependencies of systems and the impacts of actions and/or interventions on one or more components of a network • Mechanisms to account for the effects of climate change, such as extreme weather events and shifts in weather and climate patterns • Decision-support systems that consider the interdependence of infrastructure assets

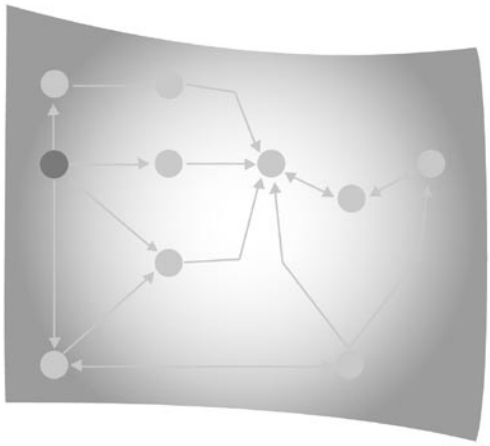


Technology Evaluation

To develop tools to evaluate the field performance of existing infrastructure systems and to predict the performance of new technologies and materials.

In the next decade, municipalities and other CIS owners will be able to more effectively evaluate proposed new technologies and compare them with their current practice, using a database of accurate information about the in-situ performance of existing products and materials. Once installed, new materials and products will be monitored for their performance over time.

Technology Evaluation	
Major Challenges	**Technology Needs**
• The existing technology evaluation mechanisms available to operators of CIS are under-utilized. • Performance requirements are not properly defined. • Assessment and monitoring is required over long time periods, and there is a lack of accelerated laboratory and field-testing capabilities. • Acceptance of a new technology often requires IMBY (in my backyard) proof of performance. • There are no mechanisms to share the risks involved in evaluating or implementing new technologies.	• Evaluation and certification mechanisms of CIS technologies that are widely recognized and used • Benchmarks for assessing new or improved technologies over existing ones, including the development of performance indicators and assessments that can be applied over the life cycle of the technology or product • Accelerated testing procedures to account for the long service life of CIS • National programs of pilot/demonstration projects, including long-term monitoring of performance measures, life-cycle analysis (economic, social and environmental) and risk sharing

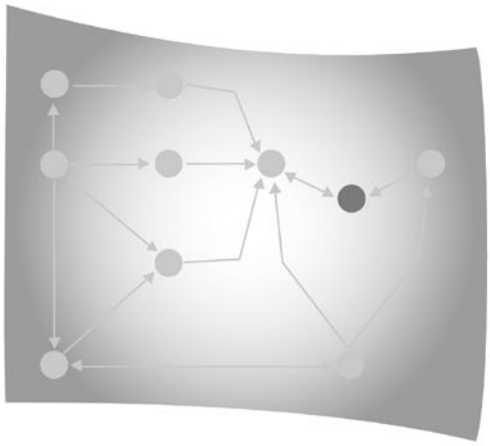


Knowledge Management

To implement processes to properly manage and share knowledge.

In the next decade, knowledge from individual and collective experience will be compiled, validated, widely disseminated and accessible. Using case studies, lessons learned and new technologies, the infrastructure industry will manage and share, through the advanced use of information technologies, a wealth of knowledge for the benefit of Canada's infrastructure owners and users.

Knowledge Management	
Major Challenges	**Technology Needs**
• There is a lack of motivation for owners of knowledge to share it with non-associated peers. • There is a need for ways to share lessons learned from successes and failures, without liability concerns. • There is a lack of resources for the collection, screening, validation and sharing of information and knowledge. • Widespread access to and dissemination of information to all CIS practitioners is difficult, and there is a wide diversity in their capacity to utilize the information received.	• Mechanisms for validating knowledge obtained from case studies, lessons learned and new developments • Use of information technology to widely share validated knowledge • Application of information technology to manage widespread access to knowledge and information • Use and enhancement of existing knowledge-transfer mechanisms such as the National Guide to Sustainable Municipal Infrastructure • Models that allow feedback looping between practice and policy

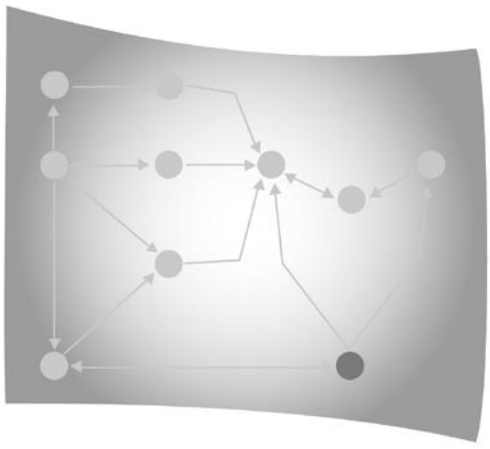


Diverse and Adaptable Technology

To increase the diversity of and access to technologies for the design, construction, maintenance and rehabilitation of infrastructure, adapted to local conditions.

In the next decade, municipalities and CIS owners will have improved access to a greater diversity of affordable technologies for the design, construction, maintenance, and particularly the rehabilitation, of CIS. These technologies will be adaptable to the many different climatic, geographical and geological regions of Canada.

Diverse and Adaptable Technology	
Major Challenges	**Technology Needs**
• There is a poor inventory of existing technology. • Sufficient choice in rehabilitation technologies is lacking. • In small or remote communities, access to technologies is often difficult. • There are no mechanisms for small communities to share the risk of adopting new technologies. • Local conditions such as climate, geography, and geology can play major roles in performance and durability. • New technologies are not being integrated into existing CIS. • There are very few standards for rehabilitation of CIS. • There is no motivation for stakeholders to incorporate new technologies and approaches because their benefits are usually poorly defined. • Collaboration and involvement of utilities, municipalities and other operators in technology development is lacking. • Barriers exist to the use and acceptance of new, innovative technologies.	• Focus on rehabilitation technologies and easy-to-use, cost-effective, durable equipment, and develop procedures for adapting them to a wide range of local conditions • Pre-qualification of new products and technologies • Demonstration and pilot projects to evaluate the long-term performance of new technologies • Risk/benefit models for the introduction of new materials • National programs of pilot/demonstration projects, including long-term monitoring performance measures, life-cycle analysis (economic, social and environmental) and risk sharing • Development of new technologies through multidisciplinary teams in partnership with public, private and research groups to ensure their fast-track acceptance and use • Mechanisms to share risks and benefits to encourage the development and use of innovative technologies • Common (uniform) performance standards for technology families • Development and maintenance of technology databases accessible to all practitioners

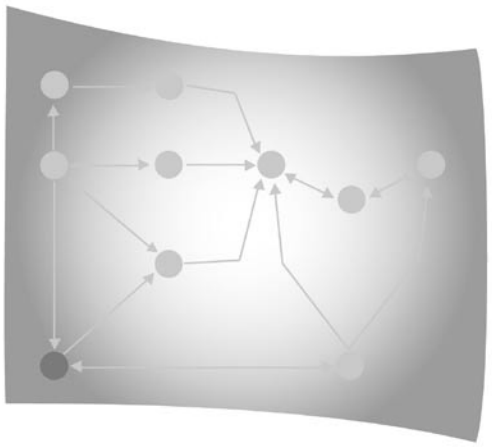


Monitoring and Control Operations

To implement technologies to optimize the operation and maintenance of infrastructure through real-time monitoring and control.

In the next decade, municipalities and CIS owners and operators will have technologies in place to monitor and control CIS operating and maintenance operations in real time. This will ensure the improvement of quality assurance (QA) and quality control (QC). Furthermore, it will provide real-time feedback, minimize response times and generate data and information to better understand the life-cycle performance of CIS. Lastly, CIS owners will have the means to meet regulatory requirements and improve systems.

Monitoring and Control Operations	
Major Challenges	**Technology Needs**
• Changing regulatory environments require infrastructure system modifications and reliable monitoring. • The development of various technologies requires an interdisciplinary approach. • The development of performance indicators and benchmarks lags technology and regulatory advances. • Regulatory CIS requirements vary by location. • There are presently inconsistencies in the type and format of data that make it difficult to monitor CIS operations. • CIS operations, monitoring and control require real-time data from a variety of sources, many of which are in harsh, limited-access environments.	• Technology that is durable and flexible enough to allow for varied conditions and changing data requirements • Systems to monitor and report condition, status and deterioration rates • Non-intrusive, non-destructive monitoring and inspection technologies • Tools for data management • Technology for life-cycle analyses • Technology trials, experimentation and monitoring • Technologies and tools to obtain the real-time data required to optimize CIS operations • Models and/or methods to relate operations data to the performance and life cycle of CIS

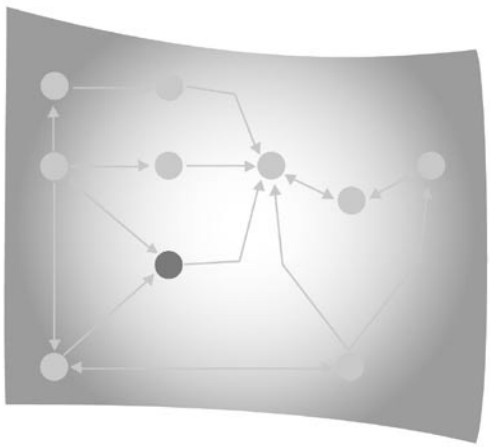


Quality Assurance and Quality Control

To expand the use of tools and processes to improve the quality of design, construction, rehabilitation, management and operation of infrastructure systems.

In the next decade, tools and processes will be available and used by municipalities and other CIS operators to ensure improved QA/QC in the design, construction, maintenance and rehabilitation of CIS. Monitoring and feedback systems will be available to assist in the evaluation of new technologies, products and materials.

Quality Assurance and Quality Control	
Major Challenges	**Technology Needs**
• The impacts of poor QA/QC on the life cycle of CIS are not well understood. • The use of QA/QC in design, construction and operation of CIS is not widespread. • Performance indicators and benchmarks that support QA/QC have not been developed, or if they exist, are very seldom used. • There has been little development of performance-based specifications in CIS and the industry generally works with prescriptive specifications. • QA/QC practices for CIS across the country are inconsistent.	• Design and dissemination of QA/QC procedures and tools • Non-intrusive, non-destructive monitoring and inspection technologies • Technologies and mechanisms, such as shared databases, for cooperation and collaboration among consultants, contractors, administrators and designers • Technologies and tools to obtain the real-time data required to optimize CIS operations • Effective, uniform procedures and tools for QA/QC field applications • QA/QC procedures focused on the performance of systems as well as on individual components • QA/QC planning tools for owners, builders and designers • Pre-qualification of products and systems based on performance

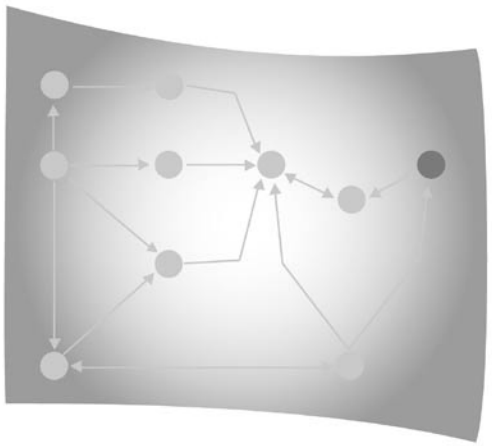


Education, Training and Outreach

To ensure that educational, training and public outreach programs meet the needs of decision makers, the workforce and the industry.

In the next decade, CIS education, training and outreach initiatives will be widespread across Canada. These initiatives, focusing on construction and rehabilitation of infrastructure, will be directed to all levels of the CIS community to ensure that consultants, operators, managers and students have the academic and practical knowledge to fulfill their obligations. The improved dissemination of knowledge, along with advocacy and outreach programs directed to the public, will lead to a better understanding of CIS, the acceptance of new, innovative and affordable technologies, as well as to the adoption of improved CIS management practices by users and decision makers.

Education, Training and Outreach	
Major Challenges	**Technology Needs**
• Qualified personnel for training and teaching purposes is in short supply. • A decline in civil engineering student enrolment in the last 10 years, combined with the retirement of experts, has caused a shortage of infrastructure experts dedicated to the advancement of CIS science. • The initial costs for the start-up of new education and training programs in CIS are very high; there are no dedicated sources of funds for these activities. • Benefits that have been realized due to proper education and training practices can be difficult to quantity. • Short-term and long-term educational goals for CIS have not been established. • Efforts in education, research, and training among academics, researchers and owners are disconnected and lack coordination and focus. • Educational opportunities need to be identified when they arise and where they are most needed.	• New IT tools for better use of existing educational resources • Common, standardized, expanded curricula, along with improved teaching methods and materials • Certification standards • Validation and testing procedures for the evaluation of new materials • Case studies and pilot projects • Outreach programs to educate decision makers and the public of the value of innovation in infrastructure



Recommendations

Following the Town Hall Meetings, the Expert Panel reviewed all the material obtained and developed a set of recommendations related to the objectives.

While the objectives are to be achieved within the next 10 years, the recommendations are for immediate action by the CIS community. These recommendations ensure that everyone involved in the Canadian CIS industry has a role in achieving the goals, objectives and vision of the CIS industry as represented by the TRM.

The recommendations are:

- **To request that the federal government create a National Round Table for Infrastructure (NRTI), bringing together all stakeholders to develop a National Infrastructure Action Plan.** *An expert advisory body of the NRTI will advise on technology issues.*
- **To develop a cost-effective mechanism by which data on infrastructure inventory and condition assessment are collected from municipalities and from other owners of infrastructure as they apply for Infrastructure Canada and other funding.** *This is a first step toward developing a database of the national infrastructure inventory.*
- **To include life-cycle analysis in the selection of CIS projects or technologies submitted by and to municipalities.** *This will ensure optimum return on investment, increase the service life of infrastructure systems and encourage the adoption of new, innovative technologies.*

- **To request that Infrastructure Canada establish a national innovative-technologies demonstration program that could be employed by municipalities and other CIS owners to demonstrate and validate projects that use new, adapted and innovative technologies.**
- **To establish a Network of Centres of Excellence, or an equivalent, for infrastructure.**
- **To request the federal, provincial, territorial and municipal governments and industry partners to dedicate funds to infrastructure research and development.**
- **To integrate infrastructure rehabilitation and maintenance content into curricula and into continuing education programs.** *Programs and short courses should be created to increase professional, labour and administrative awareness of emerging, innovative technologies and practices in the construction, maintenance and rehabilitation of CIS.*
- **To establish an infrastructure technology transfer program to encourage the movement of technology from research facilities to the marketplace.** *The program would, in particular, support the development of new technologies within small organizations that might otherwise lack the resources to do so.*
- **That within five years, the progress and success of the TRM be measured in relation to its objectives and that the TRM be revised and updated as necessary.**
- **That the partnership of professional organizations that led the TRM and the members of the Expert Panel offer their expertise to organizations that adopt the recommendations, with the goal of helping them achieve the objectives.**

The Technology Road Map is a mechanism for the improvement and continuing coordination of CIS stakeholders who are committed to meeting the TRM objectives. An *invitation to action* is extended to all CIS stakeholders to collaborate in increasing the longevity and improving the efficiency of Canada's civil infrastructure systems, thereby ensuring the continuing health and prosperity of our communities.

Appendix

Attendees of the Technology Road Map Town Hall Meetings

We appreciate the contributions of the following CIS-TRM Town Hall Meeting participants.

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"The challenge facing Canada's CIS is significant. It requires a national action plan and a common national vision. Collectively, the CIS industry has the potential and the capability for making a positive impact on the future. You are invited and encouraged to become a leader in developing the solutions that our community needs."

Reg Andres, PEng
Chair of the CIS-TRM Expert Panel and
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TECHNOLOGY ROAD MAP OBJECTIVES

The essence of the Technology Road Map (TRM) is the 10 interrelated objectives listed below:

- Asset and Inventory Condition
- Benefits of Maintenance and Rehabilitation
- Life-Cycle Cost/Benefit Analyses
- Integration of Civil Infrastructure Systems
- Technology Evaluation
- Knowledge Management
- Diverse and Adaptable Technology
- Monitoring and Control Operations
- Quality Assurance and Quality Control
- Education, Training and Outreach