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Client Report

B-5123.3

Municipal Infrastructure Investment Planning (MIIP)

MIIP Report: A Primer on Municipal Infrastructure Asset Management

for

City of Calgary
City of Edmonton
City of Hamilton
City of Ottawa
City of Prince George
Department of National Defence
Regional Municipality of Durham
Regional Municipality of Halton
Regional Municipality of Niagara

May 2004

Municipal Infrastructure Investment Planning (MIIP)

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MIIP Report: A Primer on Municipal Infrastructure Asset Management

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1 Scope of Asset Management for Municipal Infrastructure

1.1 Why Asset Management?

Managers of mixed urban infrastructure assets in federal departments, provincial governments, municipalities, school boards, and universities, etc. have to manage a diversified set of built assets, from complex underground networks (*e.g.* water distribution, sewers) to buildings, roadway systems, parks, transit systems, and other assets collectively known as infrastructure. These built assets are subject to deterioration due to ageing, climate, geological conditions, or changes in use. Because of a lack of adequate funding and appropriate decision support technologies, certain components of our urban infrastructure have been neglected or receive only remedial treatments. Consequently, these built assets do not last their originally predicted service life, unless they undergo major rehabilitation and renewal.

Asset and property managers are faced with many challenges regarding when and how to inspect, maintain, repair, renew, and replace a diverse set of existing facilities in a cost-effective manner. There are few tools in the form of standards, guidelines, technical literature, or best practices to assist them in their decision-making. In addition, there are now many information technology (IT) solutions claiming to address the needs of municipalities; however, it is extremely difficult for *all* organizations to evaluate *all* these solutions for suitability to meet *all* their needs.

1.2 Definition of Municipal Infrastructure

Several definitions are required to advance this discussion on municipal infrastructure asset management. A more exhaustive glossary and list of abbreviations are included as Appendices A and B, respectively.

The Canadian Oxford Dictionary defines “infrastructure” as “the basic structural foundation of a society or enterprise; roads, bridges, sewers, etc. regarded as a country's economic foundation”. Many organizations are also using the term *civil infrastructure systems* (CIS) to describe this type of built asset to distinguish it from other forms of infrastructure such as computer networks.

Municipal infrastructure, a distinct portion of civil infrastructure, includes those assets managed by municipalities. These typically include, but are not restricted to, the following classes of assets: buried utilities, roads, transit systems, bridges, water/sewage treatment plants and parks. Some jurisdictions are responsible for a variety of buildings (i.e. police stations, fire halls, indoor swimming pools, arenas and community centres) but their responsibility could also extend to other types of buildings such as social housing, schools and vehicle maintenance depots.

Typically, one identifying aspect of municipal infrastructure is the diversity of assets in any one organization. That is, bridges may predominate in one municipality, whereas it could be roads or buildings in another.

1.3 Definition of Asset Management

A number of organizations have produced definitions for the term *asset management* (TAC 1999, IIMM 2000, FHWA 2002, AASHTO 2003). The following definition suits many organizations managing municipal infrastructure and it can be adopted or adapted to meet their internal needs:

> *Asset management is a business process and decision-support framework that: (1) covers the extended service life of an asset, (2) draws from engineering as well as economics, and (3) considers a diverse range of assets.*

2 Related International and National Activities in Asset Management

Asset management is neither a new term in the industry, nor a new process for municipalities. The term was first used in the construction context two decades ago to describe the life cycle of physical assets (Burns 1990). In addition, asset management is what public works officials have been doing for centuries. The following sections outline a number of international and national activities related to asset management.

2.1 International Efforts

2.1.1 Institute of Public Works Engineering Australia (IPWEA) <*www.ipwea.org.au*>

The Institute of Public Works Engineering Australia (formerly the Institute of Municipal Engineers Australia-IMEA) and the New Zealand National Asset Management Steering (NAMS) Group have jointly developed an *International Infrastructure Management Manual* (IIMM 2000). This manual is divided into five sections: introduction, implementing asset management, implementing techniques, asset management information systems, and country specific information. The manual defines asset management; introduces the concepts of total asset management and life cycle asset management; shows the benefits provided by asset management techniques; outlines best practices; provides principles and processes of asset management implementation guidelines; shows how to evaluate and implement information systems to support good asset management planning and decision making; cites case studies, and includes an implementation plan. The manual has an extensive glossary of terms related to asset management.

2.1.2 Australian National Audit Office (ANAO) <*www.anao.gov.au*>

The Australian National Audit Office is a public sector organization meeting audit service needs of parliament and commonwealth public agencies. The ANAO assists the Auditor-General by providing an objective evaluation of the performance and financial management of public sector agencies. The ANAO's *Asset Management Handbook* (ANAO 1996) helps asset managers implement asset management principles. The *Asset Management Handbook* provides an overview of asset management principles, instructions on the application of asset management principles and concepts, a selection of case studies, and a glossary of terms. The Australian National Audit Office found that:

- most organisations can benefit from proper asset management strategies;
- asset management strategies should integrate with other strategic planning processes;
- alternatives should be considered when purchasing and replacing assets;
- life-cycle costing analysis should be used;

- improved asset management can occur from proper codification of costs of assets;
- decisions about asset decommissioning should be made at a strategic level, and
- regular inspection of the condition and performance of assets, combined with careful planning for replacement, can maximize the return on investment.

The ANAO also published a better practice guide entitled the *Asset Management Guide* (ANAO 1996a). The *Guide* and *Handbook* are based on the asset management principles developed by the ANAO (1996).

2.1.3 Government of Victoria, Australia

Facing the Renewal Challenge of aging assets: Victorian Local Government Infrastructure Study (Victoria 1998) is an evaluation of asset management needs. This paper estimates that the infrastructure owned by Victorian Councils (municipalities) is worth around $ 23.3 billion in current replacement value, or approximately $ 13,000 per household. The report found that:

- asset management is a corporate and not only a technical responsibility;
- there is a strong need for good information;
- there is a requirement for planning and for establishing standards, and
- there is a need for rigorous approaches to financial and performance measurements.

This study also identifies many important asset management elements such as strategies for action, terms of reference, challenges for renewal, and financial and management reporting. It also discusses issues and constraints for both revenues and expenses for municipalities.

A newer report from the State of Victoria (2004) confirms the earlier asset management premises (Victoria 1998) and proposes an asset management plan of action for municipalities.

2.1.4 Asset Management Quarterly, International (AMQI) <*www.amqi.com*>

AMQ International (AMQI) is an Australian company that has acted since 1992 as a focal point for ideas relating to asset management. AMQI has assisted in preparing the Victorian infrastructure study (Victoria 1998) identified in Section 2.1.3. AMQI focuses on the "design and creation of new tools and techniques for asset management including high level policy models for forecasting infrastructure asset renewal, infrastructure depreciation techniques, and mentoring for policy makers and innovative performance measures" (AMQI 2002). In 1994, AMQI launched its quarterly newsletter, and Dr. P. Burns (AMQI 2002) continues to produce the biweekly international newsletter dedicated to Strategic Asset Management (SAM). AMQI's web site also hosts the "Emerging World of Asset Management" - a virtual community of discussion groups for managers of realty assets.

2.1.5 Governmental Accounting Standards Board (GASB) <*www.gasb.org*>

The US Governmental Accounting Standards Board, a non-profit organization, was established in 1984. In June 1999, GASB established a new financial reporting standard that modified the way that State and local governments report their financial results. GASB Statement 34 (*Basic Financial Statements—and Management's Discussion and Analysis—for State and Local Governments)* calls for municipal, local and state authorities to account for their assets and to identify them in their financial statements (GASB 2001). Statement 34 established and improved "standards of state and local governmental accounting and financial reporting that will result in useful information for users of financial reports and guide and educate the public, including

issuers, auditors, and users of those financial reports". "Long lived" assets such as buildings, land and infrastructure must now be reported in a financial statement (the term "long lived" refers to assets that have initial useful lives beyond one reporting period).

Statement 34 provides two methods for reporting the infrastructure owned by governmental authorities: (1) straight depreciation method (traditional), referred to as the Standard Reporting Approach, and (2) the Modified Approach (preservation). The traditional approach to reporting the annual cost of using capital assets involves the operating, maintenance and repair costs, as well as depreciation costs. The Modified Approach provides information on the current physical condition and long-term maintenance needs of government's infrastructure assets. In the Modified Approach, infrastructure assets do not have to be depreciated if: (1) an asset management system is used, and (2) assets are maintained at a pre-established condition. The GASB implementation schedule is progressive and is dependent on the size of the agency (GASB 2003): "… all governments have a minimum of two years to get ready to publish the new financial statements, and smaller governments have as many as two additional years to prepare (The largest governments must prepare the new statements for fiscal years beginning after June 15, 2001). Governments also have an additional four years to meet the new requirements for reporting infrastructure".

The authors believe the introduction of GASB Statement 34 has contributed to the recent "popularity" in asset management in North America and will continue to promote asset management techniques.

2.1.6 Federal Highway Administration (FHWA), US Department of Transportation <*www.fhwa.dot.gov*>

FHWA has initiated several programs to address the issues of infrastructure and asset management. In 1999, FHWA established the Office of Asset Management. It is one of four offices within FHWA's Office of Infrastructure. Its mission is to bring state-of-art management system technology and best practices to US States and local agencies and to provide leadership and expertise in the management of highway infrastructure assets. The Office has three key responsibilities:

- provide national leadership in asset management for the highway programs;
- develop asset management policies for pavement and bridge systems; and
- partner with the American Association of State Highway and Transportation Officials (AASHTO) and others to conduct nationwide programs.

FHWA has published a number of primers on asset management (FHWA 1999), life cycle cost analysis (FHWA 2002a), GASB 34 (FHWA 2000) and data integration (FHWA 2001). One report outlined the background of the GASB reporting model (FHWA 2000), its requirements, and the implementation issues. The FWHA primers on (FHWA 2000; FHWA 2001) include comprehensive glossaries of asset management terms.

FHWA (2002a) has also developed software and user guides for two applications: Pavement Life cycle Cost Analysis (LCCA) and Highway Economic Requirements System/State Level (HERS/ST). LCCA is an economic tool linked to project level decision-making. The tool applies probabilistic and deterministic approaches to find the lowest cost investment option to obtain the maximum return on pavement maintenance funding. HERS/ST (FHWA 2001a 2002) is an engineering and economic analysis tool using engineering standards to identify deficiencies in a

highway system. HERS/ST applies economic criteria to select the most cost-effective mix of improvements for a system-wide highway implementation plan.

2.1.7 American Association of State Highway and Transportation Officials (AASHTO) <*www.aashto.org/aashto/home.nsf/FrontPage*>

The American Association of State Highway and Transportation Officials (AASHTO 2003) initiated a Task Force on Asset Management in 1998. The AASHTO Task Force on Transportation Asset Management, *Strategic Plan 2000-2010*, was adopted in December 2000. The mission of the *Asset Management Strategic Plan* is to "champion concepts and practices that integrate transportation investment decisions regarding operation, preservation and improvement of transportation systems for member agencies". The goals of the $ 3 million (US) project are three-fold:

- develop and document strategies and policies for asset management;
- communicate with member agencies about asset management and transfer technology, and
- assist members with evaluation and implementation of their asset management plans.

The goal of the Task Force is to develop information on transportation asset management and to apply these findings in producing a *Transportation Asset Management Guide* (AASHTO 2003b). The Guide formalizes asset management principles in an effort to assist agencies to improve their asset management practices. The guide also covers the organizational allocation of resources and how asset management "best practices" apply to a wide variety of functions. The final report of the guide is available on the AASHTO (2003a) web site.

2.1.8 National Association of College and University Business Officers (NACUBO) <*www.nacubo.org*>

The National Association of College and University Business Officers has published *Managing the Facilities Portfolio* (NACUBO 1991), which is a seminal document that provides a detailed methodology for the long-term financial planning for facility renewal and adaptation. American colleges and universities own and operate an extensive array of physical assets, ranging from housing to laboratories, offices to classrooms, and roads to buried utilities. To address the challenge of eliminating the estimated $ 60 billion facility renewal and replacement backlog (Rush and Johnson 1988), NACUBO developed protocols for institutional facility renewal. The association was one of the first organizations to recommend the use of the "facility condition index" or FCI as an indicator of the relative condition of an asset. The facility condition index is the ratio of the cost of deficiencies to the current replacement value (CRV).

2.1.9 Midwest Regional University Transportation Center - University of Wisconsin <*www.mrutc.org*>

A recent report from the Midwest Regional University Transportation Center (MRUTC 2002) has identified a number of shortcomings in the field of transportation asset management. These include duplication of research efforts and a need for collaboration, conservation and community focus, interdisciplinary focus, and communication and leadership.

2.1.10 Association of Metropolitan Sewerage Agencies (AMSA) <*www.amsa-cleanwater.org*>

The Association of Metropolitan Sewerage Agencies (AMSA 2003) represents 300 public agencies and organizations related to wastewater treatment in the USA. AMSA is active in

publishing reports, conference proceedings and a monthly online newsletter entitled the *Clean Water News (AMSA 2003a).*

2.1.11 Water Infrastructure Network (WIN) <*www.win-water.org*>

The Water Infrastructure Network (WIN) was formed in 1999 (WIN 2003). A recent WIN report is entitled *Clean and Safe Water for the 21st Century: A Renewed National Commitment to Water and Wastewater Infrastructure* (WIN 2003a). A second report, *Water Infrastructure Now: Recommendations for Clean and Safe Water in the 21st Century* (WIN 2003) provides recommendations for infrastructure financing.

2.1.12 Consolidated Municipal Infrastructure Programme (CMIP) <*www.dplg.gov.za*>

The Consolidated Municipal Infrastructure Programme is a South African initiative (CMIP 2003). The primary objectives of CMIP are to provide funding to municipalities to minimize backlogs through the provision of basic levels of infrastructure services to low-income households and to support the housing program of the government.

For the CMIP program's 10-year time frame, it provides grants to municipalities for services such as water, roads, solid waste removal and community lighting. Its aim is to enhance long-term sustainability and to improve service delivery. It also focuses on improving the municipalities' ability to improve contract management and their operation and maintenance capacities. CMIP funds mainly three categories of infrastructure:

- installation of new trunk and connector infrastructure for greenfield development;
- upgrading of existing infrastructure;
- rehabilitation of existing infrastructure, and
- rehabilitation of support services.

CMIP has also developed a web site dedicated to CMIP program information where projects can also be viewed online using Geographical Information System (GIS).

2.2 Canadian Asset Management Efforts

2.2.1 National Guide to Sustainable Municipal Infrastructure <*www.infraguide.gc.ca*>

The *National Guide to Sustainable Municipal Infrastructure* (Guide 2003) is funded under the Infrastructure Canada Program (ICP) and managed by the Federation of Canadian Municipalities (FCM) in partnership with the National Research Council of Canada (NRC). The four-year project that started in 2001 has a budget of $ 25.7 million. The *Guide* provides a road map to the best available solutions (i.e. *Best Practices*) for addressing municipal infrastructure issues. It also serves as a focal point for the Canada-wide network of practitioners, researchers, and municipal governments focused on infrastructure operations and maintenance. The *Guide* addresses six target areas:

- environment protocols,
- municipal roads and sidewalks,
- decision-making and investment planning,
- transit,
- potable water (production and distribution), and
- storm and wastewater.

Stakeholders from Canadian municipalities and infrastructure specialists from across Canada assist engineering consultants to develop these *Best Practices*. The *Best Practices* help municipalities identify needs, evaluate solutions, and plan for long-term sustainable solutions for improved infrastructure. A total of 21 *Best Practices* have been published to date.

2.2.2 Canadian Institute of Chartered Accountants (CICA) <*www.cica.ca*>

The Canadian Institute of Chartered Accountants (CICA) published a report (CICA 1990) on *Accounting and Reporting for Physical Assets by Governments* and has recently published a second report on physical assets dealing with *Accounting for Infrastructure in the Public Sector* (CICA 2003). The second document explores alternatives for the reporting and accounting of infrastructure as assets. This report addresses issues such as how the lack of information can directly affect the financial management of existing infrastructure systems as well as the financial planning for new systems. The report concludes that public sector agencies should:

- report infrastructure as an asset;
- provide financial, user costs, and component breakdown and condition information about infrastructure;
- depreciate infrastructure over its service life, and
- provide deferred maintenance costs.

2.2.3 Transportation Association of Canada (TAC) <*www.tac-atc.ca*>

The Transportation Association of Canada (TAC 2003) is a national association of approximately 475 members. These include federal and provincial transportation departments, municipalities, private-sector firms, and academic institutions. In 1998, TAC's Strategic Planning Committee identified 11 key municipal transportation challenges common to all municipalities. The main issues and challenges include funding/financing, technology deployment, affordable asset management system, safety, standards and guidelines, environmental considerations, public information and education/training.

The Transportation Association of Canada (TAC 1999) has published a *Primer on Highway Asset Management* defining asset management, identifying its benefits, listing the components of an asset management system, discussing critical success factors, and itemizing a seven-step implementation plan. The potential for partnering and benefits are also illustrated in the report. TAC (2003a) also provides an electronic database related to *Maintenance and Construction Best Practices.*

In addition, TAC is in the process of completing a Guide to bridge management practices. This new Guide will include information about bridge maintenance, deficiencies, evaluation and assessment. The new Guide is scheduled for release in 2004 (TAC 2004).

2.2.4 Transport Canada (TC) <*www.tc.gc.ca*>

Transport Canada's role is to develop transportation policies to maintain a high level of safety, security, and sustainability in transportation systems in order to meet the economic, societal, and environmental needs of Canada. The *National Highway System Condition and Needs Update* (2004) has estimated the cost of correcting all deficiencies to the National Highway System at $ 17.4 billion (1997 dollars).

2.2.5 Infrastructure Canada (IC) <*www.infrastructurecanada.gc.ca*>

In the 2001 Canadian Federal Budget, the Government of Canada announced the start of Canada Strategic Infrastructure Fund (CSIF), a $ 2 billion program for large-scale strategic infrastructure projects (CSIF 2003). The goals of the program are to improve quality of life and further economic growth. The CSIF will partner with municipal and provincial governments, and the private sector. Although still in its initial stages, the CSIF has recently announced funding of a wide range of projects including highway twinning, floodway expansion, transit upgrading, improved sewage treatment, and water distribution improvements (CSIF 2003).

Also announced in the 2001 Budget, was the National Infrastructure Canada Program (ICP) with its funding level set at $ 2.05 billion for six years (ICP 2003). The ICP is based on partnerships with provincial and territorial governments, municipal governments, First Nations, and the private sector. The key priority for ICP is green infrastructure; that is, infrastructure that serves to preserve or enhance the quality of our environment. Recent announcements included funding of projects related to water infrastructure, water quality improvements, transportation infrastructure, energy efficiency, and "greening" of facilities (ICP 2003).

2.2.6 Municipal Infrastructure Investment Planning (MIIP) <*www.nrc-cnrc.gc.ca/irc/uir/miip*>

The Municipal Infrastructure Investment Planning (MIIP 2003) project is a research initiative of the National Research Council Canada and a number of municipalities. Its objectives are:

- evaluating existing tools and techniques to assist municipal infrastructure investment planning, and
- developing prototype tools and techniques for asset managers to better manage their municipal infrastructure.

Specific deliverables of the MIIP project include: evaluations of Information Technology (IT) tools, surveys of the use of asset management in practice, case studies of asset management, and guidelines and manuals on asset management.

2.2.7 Municipal Infrastructure Data Standard (MIDS) <*www.tricom.org/mids*>

The Municipal Infrastructure Data Standard (MIDS 2003) is a joint venture focusing on public works and information technology in the Province of Ontario. It is sponsored by a "Tri-Committee for the Utilization of Information Technology in Public Works", consisting of Ontario Good Roads Association (OGRA), the American Public Works Association (APWA-Ontario Chapter), and the Municipal Engineers Association (MEA). It is the goal of the MIDS program to have 100% acceptance by Ontario's municipal governments.

MIDS is attempting to provide a set of definitions for municipalities that specifies how to store and manage information about civil infrastructure systems. Currently, the project focus is on roads and trails, water distribution, wastewater and storm water collection, railroads, and landscape. MIDS will assist municipalities and other infrastructure owners to design and implement their infrastructure database and to ensure conformance across the various infrastructure networks. MIDS uses an object-oriented approach to identify and classify infrastructure objects. A computer aided design (CAD) reference manual has been developed (MIDS 2003).

2.2.8 National Infrastructure Action Plan <*www.csce.ca/TRM*>

The Civil Infrastructure Systems (CIS) Technology Road Map (CSCE 2003; 2003a) is a joint initiative between the Canadian Council of Professional Engineers, Canadian Public Works Association (CPWA), and the Canadian Society for Civil Engineering (CSCE), supported by the National Research Council. It objectives are:

- to promote and build support for ongoing long-term "Holistic Investment Approach" in innovative technologies to renew and enhance Canada's infrastructure;
- to adopt the CIS Technology Road Map (TRM) as a blueprint for the renewal and enhancement of Canada's infrastructure, and
- to develop a national shared vision between the partners.

2.2.9 Municipal Infrastructure Management System (MIMS) <*www.albertamims.org*>

MIMS (2003) is a $ 2 million Alberta initiative focusing on an "easy-to-use" GIS approach to infrastructure management for small municipalities. Specifically, MIMS deals with capital planning, financial management, and decision-making. The stated MIMS priorities are to ensure that an easy-to-use, affordable infrastructure management "Tool Set" for road, water system, storm and sanitary networks, solid waste management, and municipal building is available to small and medium-sized Alberta Municipalities.

MIMS includes features such as multi-user access, user security protection, reports and enhanced spatial capabilities such as search/navigate, import wizards, query, link, distance measure, thematic mapping, and linear referencing. MIMS consists of four Tool Sets. The first tool addresses how municipalities start the process of infrastructure management. The second tool, MIMS Data Lists, defines the information that municipalities should collect, in order of importance. The third tool, MIMS Specifications, defines how to collect the required information. And the fourth tool, MIMS Registry, provides a software tool to put the information collected in a centralized digital environment. MIMS also assists municipalities to standardize the format of information and to identify what they own, its worth, its condition, and where it is located.

MIMS (2003) Version 3.2 is currently available. The GIS components of MIMS are directly related to the attribute data and the user can query the GIS map to locate assets and to display their attributes. Data can be downloaded to standard spreadsheets such as Microsoft Excel®. The thematic mapping of the GIS permits the user to query the MIMS database, for example "Give me all the poor roads in this region that were built before 1990".

The number of MIMS users has expanded from the original 5 to 30 pilot sites and MIMS has more than 100 users including a number of consulting engineers. The original 5 pilot sites have completed their infrastructure data gathering and now have access to their infrastructure inventory and condition assessment using the MIMS software. MIMS Version 4.0 is expected shortly.

2.2.10 Ontario Municipal CAO's Benchmarking Initiative <*www.caobenchmarking.ca*>

The Ontario Municipal Chief Administrative Officers' (CAO) Benchmarking Initiative (OMBI) is a partnership project to encourage service excellence in municipal government. OMBI (2003) was initiated by the chief administrative officers of 11 regional municipalities and three cities – Toronto, London, and Thunder Bay. The purpose of the project is to identify and develop

performance measures, to capture performance data, and to analyze and benchmark results. This is in an effort to identify best practices of service efficiency and quality in Ontario municipalities.

OMBI intends to identify municipalities with results that are in the "high performance zone" and advertise the procedures from these municipalities as "best practices" for others. Currently there are over 15 participating municipalities in the program, representing over 80% of Ontario's population. The initiative's long-range plan is to have the OMBI model cover different municipal functions and, eventually, to include more municipalities.

2.2.11 Municipal Performance Measurement Program (MPMP) <*www.mah.gov.on.ca*>

In 2000, the Ministry of Municipal Affairs and Housing (MMAH) implemented a mandatory program in which all Ontario municipalities will annually measure and report their performance in nine core service areas: water, wastewater, solid-waste management, land-use planning, local-government administration, roads, transit, fire, and police. The goals of the Municipal Performance Measurement Program are:

- promote better local services, continuous improvement in service delivery and clear government accountability;
- improve taxpayer awareness of municipal service delivery, and
- compare costs and level of performance of municipal services both internally, year to year, and externally among municipalities.

MPMP has brought together 55 municipalities of varying sizes to develop broad efficiency and effectiveness measures in 12 service areas, which the municipalities chose themselves. With the creation of MPMP, municipalities have the start of a common method for producing performance information about their services. Once the base of MPMP data is available for analysis, best practice reports will offer guidance and advice to local service providers about efficient alternative approaches to delivering service. The MPMP program is a component of the provincial government's effort to improve municipal accountability and report on their performance to taxpayers. The results provided from the benchmarking include information on municipal performance in area such as:

- operating costs for government as a percentage of total municipal operating costs;
- operating costs for collection, treatment and disposal of wastewater per mega litre;
- number of wastewater main backups per 100 kilometres of wastewater mainline;
- percentage of wastewater estimated to have by-passed treatment;
- operating costs for treatment and distribution of drinking quality water per mega litre;
- number of breaks in water mains per 100 kilometres of water main pipe per year, and
- number of days for boil water advisories.

2.2.12 Sustainable Water and Waste Water Act (Bill 175 MOE)

This Bill establishes a new Act, the *Sustainable Water and Sewage Systems Act, 2002*. This Act applies to those municipalities designated in the regulations that provide water and wastewater services to the public. The designated municipalities are called "regulated entities" and are required to prepare a report detailing their water and wastewater services. The report must include an inventory and management plan for the infrastructure assets providing the services,

the certification of this plan by a professional engineer, and an assessment of the total cost of providing the services including revenues. The Act specifies the total cost of providing services should include source protection costs, operating costs, financing costs, renewal and replacement costs, and improvement costs. The total cost may also include other necessary costs specified in the regulations.

2.2.13 City of Ottawa Long Range Financial Plan: First Steps <*www.ottawa.ca*>

The City of Ottawa's *Long Range Financial Plan: First Steps* outlines a financial view for the City over the next ten years (Ottawa 2002). The report is intended to increase the understanding of solutions to the challenges facing the City. It presents a number of approaches for city councillors to determine how to manage growth and provide services to residents. The City has had a population growth of 41.6% in the past 20 years.

Ottawa's long-range financial plan identifies the estimated level of expenditure needed to address ongoing needs of the City's physical assets, as well as identifying the impact of deferred maintenance activity. City staff recommends calculating the building asset renewal program on the basis of a conservative 1.5 per cent of the current replacement value of the building infrastructure. City staff also estimates an accumulated deferred maintenance amount of $ 31 million for the entire building portfolio, and, if funded at the forecast level, the accumulated deferred maintenance obligation will be eliminated by 2011.

2.2.14 City of Edmonton – Infrastructure Strategy: 2002 Update <*www.edmonton.ca/infrastructure*>

The City of Edmonton has a proactive approach to managing municipal infrastructure. The City approved its *Infrastructure Strategy* in conjunction with its *Long Range Financial Plan* in 1998 (Edmonton 2002). The City has developed a ten-year forecast of its infrastructure requirements and has begun to develop several sophisticated management tools designed to ensure that limited capital resources are invested properly.

The Office of Infrastructure of the City of Edmonton is responsible for implementing and monitoring the *Infrastructure Strategy*. This report provides an overview of significant infrastructure issues that are currently facing the City, the changing context in which these issues must be handled, and an updated assessment of the current state and condition of the City's infrastructure. The report identifies initiatives of the Office of Infrastructure and civic departments over the past two years and also identifies the future plans for meeting the objectives of the *Infrastructure Strategy*. The report also outlines the infrastructure gap and its impact on the City's economic development prospects and quality of life. The report states the majority of the City's infrastructure is in fair to good condition, but specific areas that are in poor and critical condition continue to adversely affect the quality of life. Prolonged under-funding of both rehabilitation and new projects will compromise the City's capacity to provide services, promote economic development and ensure safety and a high quality of life in Edmonton.

The Office of Infrastructure has developed a consistent ranking system to evaluate the state and condition of existing infrastructure. Three key areas of infrastructure assets are evaluated: physical condition, demand/capacity (ability of infrastructure to meet demands) and functionality (ability to deliver and service/program needs). This innovative ranking system facilitates improved comparisons of the condition of disparate infrastructure elements, e.g. roads to drainage, or parks to information systems. It also supports improved decision-making and capital

project prioritization; helps the city manage its infrastructure; provides a framework to validate public expectations and promotes awareness of infrastructure issues. The City of Edmonton's *Infrastructure Strategy: 2002 Update* (Edmonton 2002) is included as Appendix C in this Primer.

2.2.15 City of Winnipeg <*www.city.winnipeg.ca*>

In April 1995, the committee on Works and Operations recognized the needs to adopt a Strategic Infrastructure Reinvestment Policy (SIRP) for Winnipeg (2000, 2003). A task force was established with participants from the government, business, labour and academic communities. Winnipeg recognized that it had a large infrastructure deficit and the SIRP Task Force was charged with the responsibility of drafting a plan with the following goals:

- document the current infrastructure condition;
- identify investment needed for upgrade and strategic investment;
- establish a plan to fund infrastructure investment;
- identify such legislative and other amendment(s) required to facilitate implementation of the financial plan, and
- recommend a "Strategic Infrastructure Investment Policy".

The city recommended that it: (1) invest more in infrastructure, (2) make strategic investments with the dollars they have, and (3) find ways to reduce the magnitude of the infrastructure deficit.

2.2.16 Canadian Association of University Business Officers (CAUBO) <*www.caubo.ca*>

The Canadian Association of University Business Officers (CAUBO), founded in 1937, represents the chief administrative and financial officers of over 100 universities and affiliated colleges in Canada. The CAUBO conducted a survey in 1999 with the objective of measuring the extent of accumulated deferred maintenance (ADM) on Canadian university campuses. A sub-objective was to provide information on identifying best practices and recommendations for dealing with the problem of ADM. A report, entitled *A Point of No Return: The Urgent Need for Infrastructure Renewal at Canadian Universities* (CAUBU 2000), was based on data from 51 universities, accounting for approximately 87.5% of Canada's total university enrolment. The CAUBO report indicated there was an ADM of $ 3.6 billion on an asset portfolio of $ 37 billion. The average facility condition index (FCI) for Canadian universities was 11.3%, which is considered by the CAUBO to be too high. To reach the recommended target level of 2% FCI, a capital investment of $ 3 billion was required, as soon as possible.

2.2.17 Canada Mortgage and Housing Corporation (CMHC) <*www.cmhc-schl.gc.ca*>

Canada Mortgage and Housing Corporation (CMHC) has published a number of related studies to help municipalities in the area of long range planning (CMHC 1992, 1992a, 1994, 1995, 1996, 1999, 1999a)

The purpose of the study in *An Assessment of Municipal Infrastructure Information Needs* (CMHC 1995) was to identify information gaps and examine issues and problems related to the quality and accessibility of information related to municipal infrastructure. The results of the survey indicate that most individuals rely on professional journals, municipal colleagues, and consultants. Most respondents confirmed the Internet would be the best medium for information dissemination.

Alternative Methods of Financing Municipal Infrastructure (CMHC 1999) serves as a background document for the other subsequent studies. It looks at infrastructure finance generally - the evolution of the issues, the challenges facing municipalities, and different financing methods. The report evaluates infrastructure financing mechanisms that are alternative or supplementary to government financing. *Alternative Methods of Financing Municipal Infrastructure* identifies a large expenditure gap, in the tens of billions of dollars, related to both upkeep of existing facilities and new requirements.

Provision of Municipal Infrastructure Through Demand Management: Guidebook and Case Studies (CMHC 1999a) looks at the ability of demand management measures to contribute to meeting future water and wastewater infrastructure demands. Demand management deviates from traditional water and wastewater system planning by focusing on why demand peaks occur and how to reduce them. Demand management aims at shaping demand, as a precursor to meeting it. The study describes demand management techniques, identifies how to tailor programs to community needs, and introduces tools for planners, engineers, and administrators to reduce water use and wastewater flow by reducing leaks, inflow and infiltration. The study discusses the engineering considerations of water and wastewater conveyance and treatment systems that assist in ensuring that public health and the environment are protected. It provides a balanced perspective of demand management considering risks, effectiveness, and costs.

2.2.18 Sault Ste. Marie Innovation Centre (SSMIC) <*www.ssmic.com*>

The Sault Ste. Marie Innovation Centre's (SSMIC 2003) Integrated Geomatics Service (IGS) provides state-of-the-art technology and design for organizing and storing municipal data. Currently SSMIC has implemented a municipal utilities model for the Corporation of the City of Sault Ste. Marie and the Public Utilities Commission. The IGS technology, based on a GIS platform, can model “object-oriented” data with specific attributes and/or values. This provides the clients with a decision support tool for monitoring daily operations and for long-range planning, including a wide range of information including assessment, taxation, electoral, routing, public works, permits, sewage, electrical, water treatment, roads, and administration. IGS uses the Web to share spatial data, and the information that can be extracted from it, among all the stakeholders of the corporation including; managers, engineers, planners, field workers, operators, contractors, citizens, tourists, businesses, and investors.

IGS covers different subject areas as: land base, buildings, administrative limits, transportation, water distribution, wastewater collection, electricity distribution, and telecommunication. A GIS-based address locator is now live on the web site (SSMIC 2003).

3 Relationship between Asset Management and Information Technologies

Many of the available tools in asset management are Information Technology (IT) solutions such as relational databases, each claiming to provide solutions to one or many of the municipal infrastructure disciplines (roads, bridges, buried utilities, buildings, etc.). Some of the existing applications address niche markets whereas some focus on generalized solutions. Some asset management tools address one or more processes in the industry: asset inventory, computerized maintenance management systems (CMMS), preventive maintenance, work order management, condition assessment, or maintenance scheduling. There is also a wide range of ownership issues. For example, some tools are “home-grown” applications developed by staff or consultants; some can be purchased by the smallest of municipalities or with limited resources,

and some are large integrated systems requiring specialists to develop the application, populate the database, and maintain the data.

3.1 Observations about IT in Asset Management

It has been observed that existing asset management tools in use in municipalities today have much in common:

- No one application can do everything;
- Some tools perform certain tasks better than other products;
- Each is constantly being improved and expanded; and
- All want increased market share.

The following observations pertain to the asset management user society, in general:

- Many organizations now have large volumes of loosely-structured data;
- Many data formats, standards, protocols, conventions and databases co-exist in one organization;
- An organization's proficiency in asset management, or with a specific asset management tool, can vary from discipline to discipline or from region to region;
- Organizations are constantly changing;
- Corporate “legacy” computer systems will always exist;
- Organizations continually upgrade their software; and
- Money and time are scarce resources.

As a follow-up to these two sets of observations, the following assertions are made about software tools in the domain of asset management:

- They all must share their data with both complementary and competing products;
- There is no panacea for any one organization, let alone one solution for the entire public works world, and
- It is impossible for any one individual or organization to know everything about every facet of every application available in the entire domain.

3.2 IT Frameworks for Asset Management

Every software application has an underlying data structure. It is important that users understand the application's data structure as it controls both the ways that data are collected, stored, and retrieved and the way the software can be used. In general, these software tools assist in classifying, storing, and retrieving data, but the tools can also enforce a specific methodology on the users. There are three major types of database structures: simple, relational and object oriented. However, some applications use a combination of these three types of databases or can have their database emulate other types of databases. In some instances the data structures are developed by the application's programmers or off-the-shelf (OTS) databases are modified to suit the application or storage requirements.

A number of asset management applications use simple databases. This is the simplest form of database structure consisting of records each having a number of predetermined fields, as shown in Figure 1. Because simple databases have been around and used successfully for decades, they are normally very reliable.

Field	Record ID	Type	Value ($)	Manager	Telephone	Location
Asset 1	1	Road	50,000	Bob	X-123	Laurier St.
Asset 2	2	Water	100,000	Bob	X-123	Laurier St.
Asset 3	3	Sewer	250,000	Tom	X-321	Ogilvy Ave.
Asset 4	4	Building	1,000,000	Tom	X-321	Ogilvy Ave.

Figure 1: Simple Database Structure

A relational database is one that is based on the model developed by E.F. Codd at IBM in 1970. In relational databases, the data items and relations between them are organized in pre-described tables from which data can be accessed or reassembled in many different ways. A table is a collection of records and each record in a table contains the same fields, as shown in Figure 2. Certain fields may be designated as keys, which means that searches for specific values of that field will use indexing to speed them up. Structured Query Language (SQL) is the application program interface to a relational database for interactive information queries and gathering data for report. Many current software tools use relational database structures. Figure 2 illustrates a typical relational database structure. In this figure, the Asset Table (a) lists the different fields for the asset records; these are relationally linked to the Manager Table (b) containing shared data about the manager such as Name, Location, and Telephone Number.

Record ID	Type	Value ($)	Manager Key
1	Road	50,000	**K1**
2	Water	100,000	**K1**
3	Sewer	250,000	**K2**
4	Building	1,000,000	**K2**

(a) Asset Table

Manager Key	Name	Location	Tel.
K1	Bob	Laurier	X-123
K2	Tom	Ogilvy	X-321
K3	Bill	Laurier	X-456

(b) Manager Table

Figure 2: Relational database structure

The advantages of a relational database over a simple database can be seen in the reduction of data duplication for specific fields (e.g. Manager, Tel # and City) in Figure 1.

An object-oriented database (OOB) is a database in an object-oriented programming environment. Data are stored as classes of objects as well as operations or methods that can be used on these data. For example as shown in Figure 3(a), an asset is a class of objects that has a number of subclasses: road, water, sewer, or building. A road is a subclass of objects that inherits its parent's attributes and can also have of its own subclass attributes (i.e. Area = Length x Width). Whereas, a sewer is a subclass of object that can have completely different attributes to that of the road (i.e. Area = πr^2). In an object-oriented structure or "schema", the relationships are displayed in "graphs" showing both connectivity and inheritance, as shown in Figure 3(a). The actual data are called "instances", as shown in Figure 3(b), each having its own object identification or OID and pointing to related OIDs.

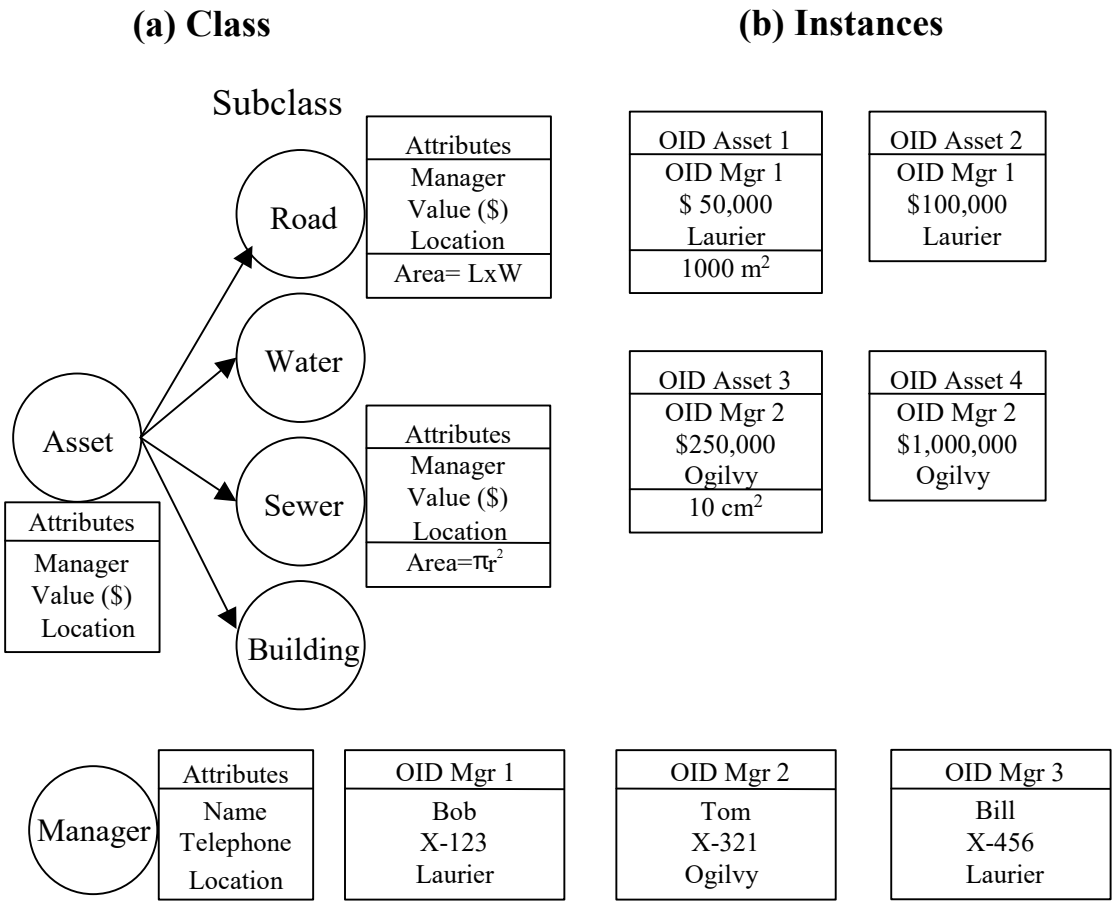

Figure 3: Object-Oriented Database Structure or Schema

The database structure used for an application is selected by the organization developing the software; however, there can be the possibility in the program of creating additional tables, records or fields, as and when required. Typically, a designated “on-site administrator” can add or modify data tables or attributes in the organization's data structure. The administrator can also check the internal integrity of the database to ensure that records are properly linked and saved.

4 An Asset Management Implementation Strategy for Municipalities: The Six “Whats”

The following is a description of the six “Whats” that can be used to assist a municipality to establish an asset management plan.

4.1 What do you own?

Asset managers need to know the extent of their assets and the specific engineering and administrative details regarding these facilities. This “what” is typically called an inventory system. An inventory system includes a full classification, enumeration, and description of all physical assets in the municipal infrastructure portfolio (buildings, buried utilities, roads, sidewalks, curbs, bridges, culverts, land, etc.). The inventory system might also include “non-construction” assets under the responsibility of the public works organization such as vehicles, trailers, playground structures, highway appurtenances, and signage.

A standard feature in a comprehensive inventory system is a data structure that stores information about each and every different type of municipal infrastructure asset (see Section 3.2). In addition, for each and every different type of asset there should be an adequate number of fields to store the pertinent information about the different types of assets. For example, data stored about building assets should include the area, location, height, date of construction, number of floors, etc. Inventory data about buried utilities should include the location, pipe material, pipe diameter, pipe thickness, and pipe depth. However, it is virtually impossible to create a database to store all things about everything. Therefore, a sophisticated inventory system should allow the user to modify the data structure to accommodate on-site requirements. A sophisticated feature of a comprehensive system is spatially coordinated data in two or three dimensions, such as provide by geographic information systems (GIS). For more information on GIS, as it relates to municipal infrastructure, please refer to publications from the Geospatial Information and Technology Association (GITA 2001, 2003).

It is important in the North American context to mention units of measure. Hopefully, any asset management application permits the user to save and retrieve data in either imperial or metric units.

The following six tables are provided to assist the user to evaluate and compare different asset management products. The tables provide examples of more detailed information required to address the six "Whats" but they can also be used as a template for comparing different products.

Table 1 lists typical classes and subclasses of municipal infrastructure assets and provides the user with a template to record how specific data are stored. "Standard" means the classes are defined in the software; "templates" mean the additional data structures can be obtained (or purchased); "user" means the user can readily augment the data structure to record these classes, and "supplier" means the only the supplier can add this functionality.

Table 1: What do you own?

Class	Subclass	Standard	Templates	User	Supplier
Buried Utilities	Water Sewer Storm Sewer Other (Name)				
Roads	Roadways Curbs Sidewalks Drainage Culverts Standards Signs Guard Rails Appurtenances Landscaping Other (Name)				
Bridges	Road surface Deck Abutments				

	Piers Other (Name)				
Buildings	Architectural Electrical Mechanical Structural Other (Name)				
Treatment Plants	Structure Equipment Other (Name)				
Parks and Grounds	Parks Playground structures Landscaping Trees Other (Name)				
Other	Vehicles Trailers Barricades				

4.2 What is it worth?

The value of an asset can be represented in many ways:

The *historical value* is the original "book value" of the asset, i.e. the recorded construction cost. Typically, in large organizations this is the only value that is recorded and maintained.

The *appreciated historical value* is the *historical value* brought to a current value using construction multipliers that are readily available (Vanier 2000, 2001; ENR 2000). The ENR numbers are based on historical cost data (averaged over 20 cities in the USA) for two weeks of skilled labour from representative tradesmen, plus a standard weight of structural steel shapes, a standard weight of portland cement, and a standard volume of processed lumber. This price updating therefore takes into account annual inflation or deflation. It uses 1913 as the base year (value = 100). To use this approach, an asset constructed in 1960 has a multiplier of 559, whereas a multiplier of 3767 is applied for an asset built in January of 2004. Therefore, a facility constructed in 1960 for $1 million can be constructed in 2004 for $1 million X 3767 / 559 or $6.74 million.

Current replacement value is the cost of replacing an asset today. Typically, this is calculated on per unit cost (i.e. per length, area or volume). Sometimes multipliers are available for different types of construction or for different cities (RSMeans 2002).

Performance-in-use value is the prescribed value of the actual asset for the user (Lemer 1998). This value takes into account the actual performance of the asset (meaning an asset that is larger and under-utilized is not worth as much as a smaller asset that is operating above capacity).

The *deprival* cost is the "cost that would be incurred by an entity if it were deprived of an asset and was required to continue delivering programs/services using the asset" (ANAO 1996). It is a term used predominantly in Australia.

The *market value* is the value of an asset if it were sold on the open market today. In many instances, the *market value* cannot be used for municipal infrastructure; however, it is applicable to many types of assets such as buildings or unoccupied land.

A comprehensive asset management system includes at least two fields to record the value of an asset; typically organizations record the cost of construction and an estimate of the current replacement value. Sophisticated asset management systems record various types of values associated with any asset or component. In addition, a mature asset management organization records and associates all maintenance, repair and renewal costs to a specific asset. A sophisticated system calculates the present value of these costs using standard life cycle costing methods (ASTM E917 1994).

Table 2: What is it worth?

Asset Cost	Standard	Templates	User	Supplier
Historical Appreciated historical Current replacement Performance-in-use Deprival Market				

4.3 What is the deferred maintenance?

Deferred maintenance is defined as the cost of maintenance (and *not* capital renewal) that has been postponed or phased for future action that would bring the asset to its original potential. Capital renewal, on the other hand, is the replacement of an asset at the end of its service life or because of economic, obsolescence, modernization, or compatibility issues.

Standard features in a comprehensive asset management system include an itemization of all work orders raised against a specific asset. More sophisticated asset management systems include a method to calculate the Facility Condition Index (NACUBO 1991) for the various classes of municipal inventory assets in the portfolio.

$$FCI = \frac{\text{Deferred Maintenance}}{\text{Current Replacement Value}} \qquad \text{Equation (1)}$$

Table 3: What is the deferred maintenance?

Facility	Replacement Value	Deferred Maintenance	Facility Condition Index (FCI)
Building X-2	$ 6,967,000	$ 640,509	9.19%
Architectural	$ 2,345,000	$ 216,011	9.21%
Mechanical	$ 1,267,000	$ 30,241	2.39%
Structural	$ 2,134,000	$ 242,234	11.35%
Electrical	$ 1,221,000	$ 152,023	12.45%
Water	$ 23,359,000	$ 239,391	1.02%
Storm	$ 10,031,000	$ 326,239	3.25%
Sanitary	$ 6,451,000	$ 956,000	14.82%

As the simple example in Table 3 illustrates, the FCI can be used as a simple metric to rank maintenance activities; that is, the higher the FCI, the higher the priority for maintenance intervention. It can also be used as rough guide for the condition of an asset, if no other method has been implemented.

4.4 What is the condition?

The condition of an asset is understood by many to be "how an asset performs its intended function". In a more general sense, facility performance is defined as the "capability of a facility to perform the function(s) for which it is designed, used, or required to be used." (ASTM E1480-92 1998). There are many techniques to rate or rank the performance of an asset, for example: (1) satisfaction surveys, (2) subjective evaluations, (3) engineering calculations, (4) weighted factor, (5) distress-based metrics, or (6) a hybrid system. Robust protocols are not currently available for all these techniques for the full spectrum of municipal infrastructure assets. In fact, many researchers and practitioners are not in agreement as to how and whether these techniques can be used to evaluate the condition or performance of an asset.

Under the classification of *satisfaction surveys* are a number of techniques allowing the asset user to evaluate performance of an asset. Benchmarking studies (OMBI 2003) and post-occupancy evaluation (FFC 2002) fall into this class. Benchmarking rates the overall performance of an organization according to a number of predetermined key performance indicators (KPI). Post-occupancy evaluations are typically used after commissioning of a building but could also be used to rate the performance of any existing facility. Typically in a post-occupancy evaluation, an evaluation team selects a representative number of occupants or users of the service; it establishes the criteria to be rated (e.g. heating quality, water clarity, response time), and it assists the users/owners to determine the importance of each criteria. The results of the evaluations (i.e. the ranking of the levels of satisfaction from a spectrum of fully satisfied to fully dissatisfied) form the rating of the facility (Aronoff and Kaplan 1998).

Subjective evaluations rate an asset according to predefined organizational standards. Typically, scales such as 1 to 5 or "failed" to "excellent" are used to rate (or rank) the condition of the asset or its components. Descriptions of the ratings would also be provided by the organization (1 or failed -- replace asset immediately; 5 or excellent -- minimal maintenance or repair required, as new condition). Owing to the subjectivity of the evaluation process, it is difficult for these metrics to be used outside an organization.

Engineering calculations are also used to represent the performance of a specific asset component. For example, the calculation of the hydraulic flow and remaining cross-sectional area of reinforcement are ways to determine the existing performance of a section of pipe and a concrete slab, respectively.

Weighted factor condition assessment is a technique where performance characteristics of an asset are identified and weighted according to their significance to the organization. The user can then evaluate the level of performance for each of these characteristics. The weighted results are obtained by multiplying the user-assigned performance scores by the weighted factors for performance characteristics. This technique can also be extended to include different user scores and different weighted factors from any number of individuals. The performance rating of individual components of an asset can also be weighted in order to reflect their relative significance (consequence) to the operation of the overall asset. A more sophisticated weighted factor technique, called Analytic Hierarchy Process (AHP), can also be used to determine the

condition of an asset; AHP is described in detail in Section 4.6 (Saaty and Vargas 2000). The condition of an asset can be also estimated using *distress-based metrics* (Shahin 1992, Zhao et al 2001). In this method, experts develop a protocol to rate distress indicators that are the most problematic and will affect the performance of a specific asset. Weighted factors are also developed to rate the severity (low, medium, high) and the extent (area, length, depth) of the distress. Each distress indicator (e.g. pothole, sidewalk crack, misaligned sewer, root intrusion, or spalled concrete) contributes to a predetermined number of "deduct values" from a theoretically excellent mark of 100% that can varying depending of the extent (e.g. 10% of area, 1 m, 10 m^2) or severity (e.g. high, medium, or low) of the distress. This technique is used heavily for pavement and bridge management systems, but few protocols have been developed for many of the other construction domains.

A *hybrid system* employs a combination of the aforementioned methods to determine the condition of the asset. The system might be specific to one organization or shared in a limited community of users.

Table 4: What is the condition?

Condition assessment technique	Standard	Templates	User	Supplier
Satisfaction surveys Subjective evaluations Engineering calculations Weighted factor Distress-based metrics Hybrid system				

4.5 What is the remaining service life?

If the asset manager can establish the remaining service life of an asset or component, then plans can be made to replace the asset or component, life cycle costs can be calculated, budgets can be established and maintenance can be scheduled. There are a number of techniques that can be used to establish the remaining service life of infrastructure assets: demonstrated effectiveness, testing of materials or component, factor methods, deterministic curves, analytical models, or probabilistic models. Unfortunately, there are few techniques or protocols that are readily available to practitioners for the wide selection of infrastructure disciplines.

The first two methods for service life prediction are described in the Canadian Standards Association (CSA) guideline on *Durability in Buildings* (CSA 1995):

Demonstrated effectiveness implies that the service life of the asset is based on documented records of successful performance. For example, an experienced asset manager would likely have a reasonable idea of how often the specific components of an asset (e.g. bridge deck) might require replacement or could derive a service life from a review of in-house records. In essence, such types of information might be referred to as aged-based or condition-based estimates. Service life estimates for components are also provided in current service life tables, guidelines, codes, standards and other sources (HAPM 2002, CSA 1995).

Testing of materials or components offers the possibility of obtaining data that can be subsequently used in the development of models for service life prediction (ASTM E632 1996, RILEM 1989, ISO 15686, 2000). The testing may include the gathering of data either from the

periodic inspection of components or direct field measurements of performance indicators over months and years. Tests can also be used to assess the level of resistance to deterioration in relation to comparable materials or components when subjected to similar test conditions or to compare the performance of components to known standards from which the service life can thereafter be estimated. Typically, short-term tests are carried out in a laboratory setting, usually indoors, but outdoor facilities are also used. Long-term studies may be undertaken in either laboratory or field conditions.

Modelling of the deterioration process involves alternate systematic approaches: Each of these four methods below requires data obtained from either the long-term or short-term tests described above.

The *factor method* (ISO 15686-1 2000) is a weighted factor approach in which a number of independent factors contributing to the service life of an asset are identified, evaluated, and rated. Factors affecting service life (e.g. design, construction quality, load, maintenance level, and material quality) are selected and the user can rate each factor's contribution to the service life. The estimated service life is calculated by multiplying a predetermined reference service life by all of the weighted factors. This approach was first presented by the Architectural Institute of Japan (AIJ 1993) and later adopted by ISO in the development of an international standard for the calculation of the service life (ISO 15686-1 2000). The *factor method* should be used only where the requirement for accuracy is not high and the consequences of an incorrect estimate are low, for example for calculation of life cycle costs.

Deterministic curves model the deterioration of assets. Curves have been developed for a number of municipal infrastructure disciplines (Bailey et al 1989; Shahin 1992). A typical example of the deterioration is shown as the two dotted lines in Figure 4. In this approach, experts determine the shape of the curve based on research data and experiential knowledge. In Figure 4, the user's assessment of the condition of two 12 year-old assets (Assets A and B) determines their remaining service life (R.S.L.). The user must also decide what Failure State constitutes the end of the service life; in some organizations it could be Condition Rating 1, 2, 3 or higher. Lowering or raising the Failure State changes the R.S.L. for both Asset A and B. In Figure 4, Asset A with a condition rating of 6 after 12 years has a R.S.L. of approximately 8 years, whereas the R.S.L. for Asset B with a condition rating of 4 is significantly shorter.

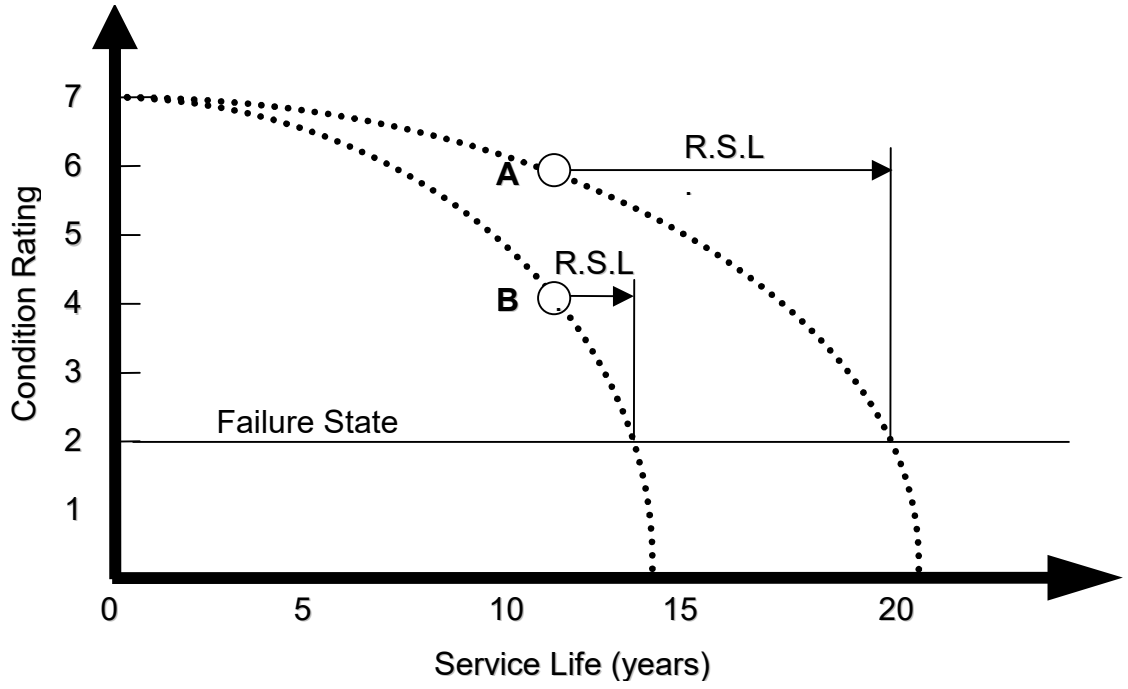

Figure 4: Deterministic deterioration curve.

Analytical models attempt to calculate the remaining service life by modelling the deterioration process. For example, calculating the rate of chloride diffusion is one method to predict the remaining service life of concrete structures: "The length of the initiation period … depends on the rate of ingress of chlorides into concrete, surface chloride concentration, depth of concrete cover, and the value of the threshold chloride level" (Lounis et al 2002). Spalling of the concrete will start once the chlorides have reached the reinforcing steel, a threshold chloride level has been reached and rusting of the reinforcing steel has started. *Analytical methods* are useful where a specific component of the assembly or network is to be maintained and where there exists considerable knowledge as to the in-service conditions.

Probabilistic models, such as Markov chain, attempt to account for the apparent randomness of the failure of components and systems. This technique predicts remaining service life based on studies of similar construction forms under test and/or in-situ conditions. Probability mass functions of performance are determined for the percentage of the sample group in each of the pre-established condition ratings, as displayed in Figure 5. A probability distribution matrix can then be developed from these results. Unfortunately these techniques require the collection of considerable amounts of data; only a few domains such as bridge (Frangopol et al 1997), trunk sewers (Kleiner 2001; Kleiner et al 2001) and roofing (Lounis et al 1998) management have developed reliable service life prediction using probabilistic models. Hybrid systems combining *factor methods* with *probabilistic models* have been suggested by Moser (2002).

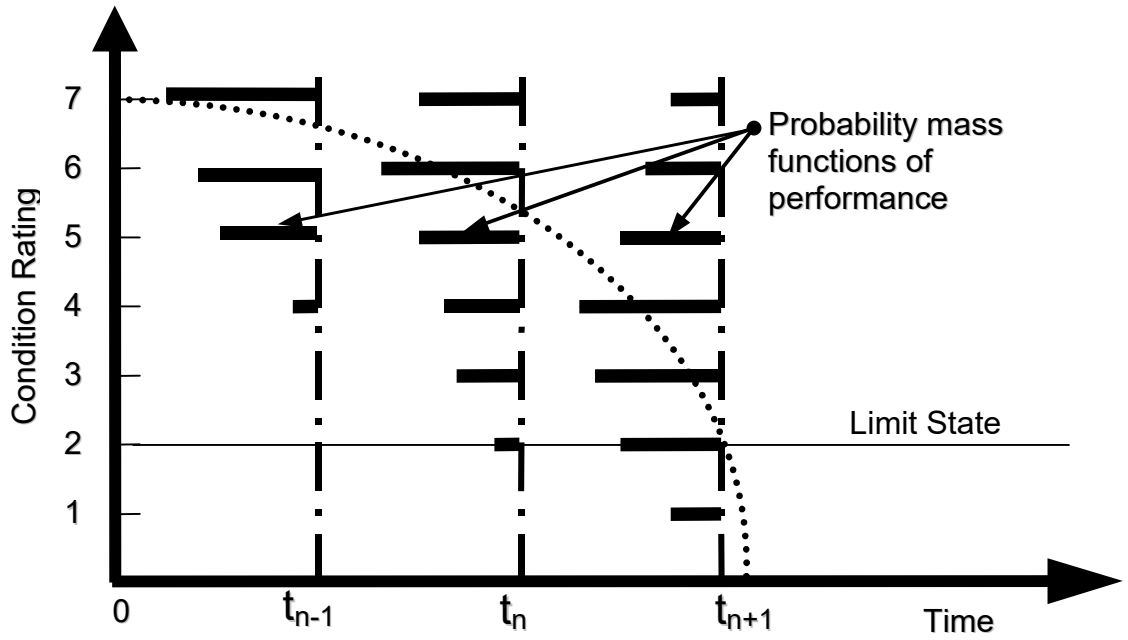

Figure 5: Probabilistic deterioration curve (from Lounis et al 1998).

Table 5: What is the remaining service life?

Methods	Standard	Templates	User	Supplier
Demonstrated effectiveness Testing of material or component Factor method Deterministic curve Analytical models Probabilistic models				

4.6 What do you fix first?

There are a number of techniques that can be used to rank maintenance. The *subjective criteria technique* relies on political, administrative or budgetary restrictions. “This project must be done” or “we have approved that project already” or “we cannot afford to do it all” are typical questions for this type of decision-making. Some organizations do their ranking based solely on safety, health or environmental concerns (Vanier and Rahman 2004). “It does not meet code” or “do you realize the health implications” are questions that might arise in this decision making process.

Expert knowledge relies on elicitation of knowledge from experts in the organization (e.g. engineers, managers, tradesmen, technicians) or from hired consultants. Their decisions are based on years of experience and what they know about the specific projects in question.

Age-based ranking relies solely on the age of the asset to determine its maintenance, repair, or renewal priority. However, this technique is flawed appear in when the ages are inaccurate or when assets with different levels of importance and risk of failure are compared. If a reliable

remaining service life can be calculated, a service life-based ranking of maintenance, repair, and renewal is much more rational than an age-based one.

Condition-based ranking first requires an objective evaluation of the condition of the asset to determine its priority for maintenance, repair or renewal, as discussed in a previous subsection. If the remaining service life can be calculated based on asset condition, it can be an effective way to prioritize maintenance, repair and renewal. However, flaws appear in this technique when the condition numbers used are subjective or when different assets are compared.

The *Weighted factor method* is a decision support tool to assist users to quantify, compare, and prioritize alternatives. In this method a number of significant characteristics of the asset or service can be selected and assigned weighted factors according to their importance to the organization. The user can then rate how the asset performs according to each of these characteristics. Results are obtained by multiplying the scores from the assigned weighted factors for each significant characteristic by the user-assigned ratings and then by adding the results. For example, the condition of the asset could account for 25% of the total, the appearance for 25%, and the remaining service life for 50%. If the user rates condition of the asset at 20 out of a possible 100, the appearance at 60 and the remaining service life at 50, the calculated result for that asset would be (20 x 0.25) +(60 x 0.25)+(50 x 0.50) or 45. Any number of evaluators could also assign their own ratings for each of the characteristics of the assets. This technique can also be extended to include different characteristic weighted factors and different ratings from selected individuals.

A more sophisticated version of the weighted factor method is called AHP or Analytic (or Analytical) Hierarchy Process (ASTM E 1765-95 1995; Saaty and Vargas 2000). In this process the overall goal of the decision making task is first established; then a limited number of Sub Goals and Alternatives are selected, as shown in Figure 6.

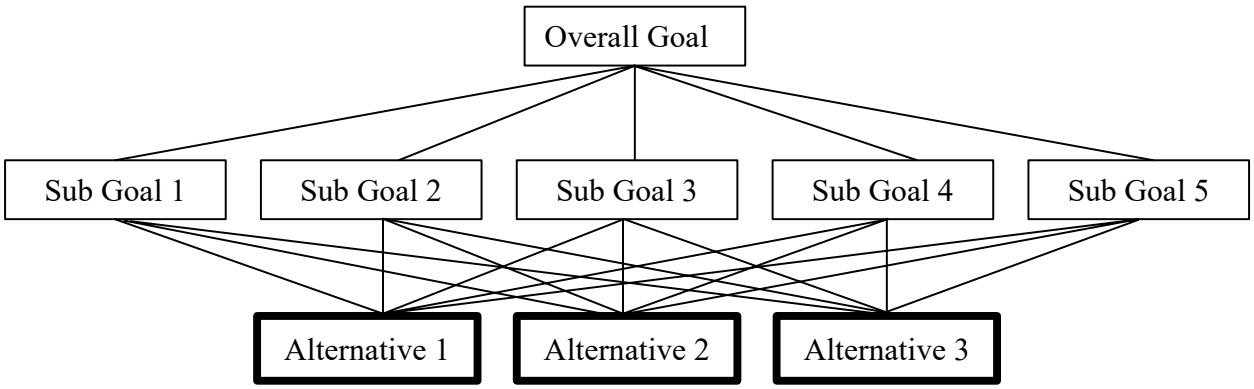

Figure 6: Analytic Hierarchy Process (AHP)

In AHP, each Sub Goal is compared one-to-one (pair-wise), with the other Sub Goals in order to develop a comparison matrix (5 x 5 in this example with 5 Sub Goals). In the pair-wise comparisons, a rating of 1 means there is equal importance of the Sub Goals under review and a rating of 9 means an extreme importance of the first Sub Goal over others. An example is shown in Figure 7. Alternatives 1, 2, and 3 from Figure 6 are then compared pair-wise separately for each of the 5 Sub Goals. That is, another five matrices of 3 x 3 are developed in this process, where each of the 3 alternatives is compared pair-wise to the others for each of the five Sub

Goals). After the two sets of comparison matrices are completed, a well-documented mathematical process (ASTM E 1765-95 1995) is used to rank the Alternatives according to the contributions of the individual Sub Goals to the overall Goal. A very good and detailed description of AHP, with examples, can be found in Saaty and Vargas (2000).

	Sub Goal 1	Sub Goal 2	Sub Goal 3	Sub Goal 4	Sub Goal 5
Sub Goal 1	1	1	2	3	9
Sub Goal 2	1	1	2	2	2
Sub Goal 3	1/2	1/2	1	1/9	2
Sub Goal 4	1/3	1/2	9	1	4
Sub Goal 5	1/9	1/2	1/2	1/4	1

Figure 7: Analytic Hierarchy Process (AHP) 5 x 5 Matrix

AHP is a comprehensive comparison tool that can be used to compare both subjective and quantifiable data and *also* can be used to give "Power Weights" to individual decision makers (e.g. the engineers have three times the "Power Weights" on technical issues). The obvious advantage of AHP is quantifiable results; however, the disadvantage is the number of comparisons required when a large number of Sub Goals and Alternatives are possible.

Multi-objective maintenance optimization is a decision-support approach based upon compromise programming methods where the simultaneous satisfaction of conflicting objectives is considered: for example, minimization of maintenance and repair costs, maximization of network performance, and minimization of risk of failure. Multi-objective optimization is a decision-making approach that uses the concept of Pareto optimality to determine the optimal allocation of funds and prioritization of assets for maintenance, repair, and replacement (Lounis et al 2002). Compromise programming is used to determine the optimal ranking of deteriorated assets in terms of their priority for repair or replacement, by achieving a satisfactory trade-off between the competing / conflicting objectives.

Table 6: What do you fix first?

Methods	Standard	Templates	User	Supplier
Subjective criteria Expert knowledge Age-based Condition-based Weighted factor Multi-objective optimization				

5 Asset Management Implementation Plan

Asset management is difficult to implement in practice as asset management means many things to many different people in a highly structured organization. For example, some disciplines in an organization may feel they already have an asset management system in place when they have implemented an inventory system. Or, some organizations may have some disciplines that are well advanced in asset management implementation (i.e. bridges, roads) but will also have many

that are lagging behind (i.e. parks, buried utilities). Or, some regions may have reached a plateau and wish to advance to a higher level not knowing that a sister discipline in another region has the tools and techniques in place to assist them. Because of these obvious differences in organizations and in any particular organization, an organization's asset management implementation plan should have a series of overlying principles established at the highest level in that organization. An example is provided in Table 7. The asset management implementation plan should:

- assess organization's current *level of implementation* in various regions and disciplines;
- set minimum criteria for data and information for all levels of implementation;
- estimate cost of implementation, and
- set timelines for next level of implementation.

Table 7: Asset Management Implementation Plan

Six "Whats" of Asset Management						
	Own	**Worth**	**Deferred**	**Condition**	**Service Life**	**Fix First**
Region #1						
Bridges	√	√	√			
Roads	√	√	√	√		
Buildings	√	Jan 2001 $ 100K	June 2001 $ 50K			
Region #2						
Bridges	√	√	Jan 2002 $ 25K			
Roads	√	√	Jan 2001 $ 50K	Jan 2002 $ 100K		
Buildings	√	√	√	Jan 2003 $ 25K		
Region #3	Jan 2001 $ 100K	Jan 2002 $ 50K				

The City of Edmonton's *Infrastructure Strategy: 2002 Update* (Edmonton 2002) is included as Appendix C in this Primer to showcase an example of a proactive approach to asset management.

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7 References

AASHTO (2003) American Association of State Highway and Transportation Officials <www.aashto.org/aashto/home.nsf/FrontPage> (5 December 2003).

AASHTO (2003a) *Transportation Asset Management Guide,* American Association of State Highway and Transportation Officials <downloads.transportation.org/amguide.pdf> (16 March 2004).

AIJ (1993) English translation of *Principal Guide for Service Life Planning of Buildings*, Architectural Institute of Japan, Tokyo.

AMQI (2002) Asset Management Quarterly, International <www.amqi.com> (5 December 2003).

AMSA (2003) Association of Metropolitan Sewerage Agencies, <www.amsa-cleanwater.org> (5 December 2003).

AMSA (2003a) *Clean Water News*, Association of Metropolitan Sewerage Agencies, <www.amsa-cleanwater.org/pubs/cleanwater/past.cfm> (5 December 2003).

ANAO (1996) *Asset Management Handbook*, Australian National Audit Office, Canberra, Australia, <www.anao.gov.au>. Check "publications" for "Better Practice Guides", (5 December 2003)

ANAO (1996a) *Asset Management Guide*, Australian National Audit Office, Canberra, Australia, <www.anao.gov.au>. Check "publications" for "Better Practice Guides" (5 December 2003).

Aronoff S. and Kaplan A. (1998) *Total Workplace Performance: Rethinking the Office Environment*, WDL Publications, Ottawa, ON, 416p, ISBN 0-921804-95-4.

ASTM E1480-92 (1998) *Standard Terminology of Facility Management (Building-Related)*, American Society of Testing Materials, West Conshohocken, PA.

ASTM E1765-95-92 (1995) *Standard Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems.* American Society of Testing Materials, West Conshohocken, PA.

ASTM E632 (1996) ASTM E632-82 (96) - *Standard Practice for Developing Accelerated Tests to Aid Prediction of the Service Life of Building Components and Materials*, American Society of Testing Materials, West Conshohocken, PA

ASTM E917 (1994) *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*, American Society for Testing and Materials, West Conshohocken, PA.

Bailey D.M., Brotherson D.E., Tobiasson W. and Knehans A. (1989). *ROOFER: An Engineered Management System for Bituminous Built-Up Roofs*, Technical Report M-90/04/ ADA218529, US Army Construction Engineering Research Laboratory, Champaign, IL.

Burns P. (1990) *Asset Management - A Global View, Building Asset Management (Don't Wait Until 2000)*, Building Science Forum of Australia, Randwick Racecourse, NSW, Australia, Jul. 25, pp. 1-15.

CAUBO (2000) *A Point of No Return: The Urgent Need for Infrastructure Renewal at Canadian Universities*, Canadian Association of University Business Officers, Ottawa, ON.

CICA (1990) *Accounting and Reporting for Physical Assets by Governments*, Canadian Institute of Chartered Accountants, Toronto, ON, 114p

CICA (2003) *Accounting for Infrastructure in the Public Sector*, Canadian Institute of Chartered Accountants, Toronto, ON. <www.cica.ca> (5 December 2003).

CMHC (1992) *Achieving Infrastructure Efficiency*, Canada Mortgage and Housing Corporation, Ottawa, ON.

CMHC (1992a) *Achieving Infrastructure Cost Efficiency/Effectiveness Through Alternative Planning Approaches*, Canada Mortgage and Housing Corporation, Ottawa, ON.

CMHC (1994) *A Synthesis of Technical Research and its Potential for Application in Linear Infrastructure Renewal,* Canada Mortgage and Housing Corporation, Ottawa, ON.

CMHC (1995) *An Assessment of Municipal Infrastructure Information Needs* (CMHC 1995), Canada Mortgage and Housing Corporation, Ottawa, ON.

CMHC (1996) *Financing Infrastructure: Evaluation of Existing Research and Information Gaps,* Canada Mortgage and Housing Corporation, Ottawa, ON.

CMHC (1999) *Alternative Methods of Financing Municipal Infrastructure*, Canada Mortgage and Housing Corporation, Ottawa, ON.

CMHC (1999a) *Provision of Municipal Infrastructure Through Demand Management: Guidebook and Case Studies*, Canada Mortgage and Housing Corporation, Ottawa, ON.

CMHC (2003) Canada Mortgage and Housing Corporation, <www.cmhc-schl.gc.ca> (5 December 2003).

CMIP (2003) Consolidated Municipal Infrastructure Programme, <www.dplg.gov.za> (5 December 2003).

Codd E.F. (1990) *The Relational Model for Database Management*, Vers. 2. Addison-Wesley.

Cost Works (2001) Cost Works Product Description, R.S. Means Company Inc., <www.rsmeans.com/costdata/cwcd.asp> (8 December 2003)

CSA (1995) CSA S478-95 *Guideline on Durability in Buildings*, Canadian Standards Association, Rexdale, ON.

CSCE (2003) *Critical Condition: Canada's Infrastructure at the Crossroads,* Canadian Society for Civil Engineering, Montreal, PQ, <www.cpwa.net/Documents/TRM_Ministerial_Brief.pdf>, (5 December 2003).

CSCE (2003a) *Innovative Technologies for Canada's Civil Infrastructure Systems,* Canadian Society for Civil Engineering, Montreal, PQ, <www.csce.ca/TRM/> (5 December 2003).

CSIF (2003) Canada Strategic Infrastructure Fund, <www.infrastructurecanada.gc.ca/csif/index_e.shtml> (5 December 2003).

Edmonton (2002) *Infrastructure Strategy: 2002 Update,* <www.edmonton.ca/infrastructure/new.html> (5 December 2003).

Edmonton (2003) <www.edmonton.ca/> (5 December 2003).

ENR (2000) *Engineering News Record: Building Cost Index History* (1915-2000), <enr.construction.com/features/conEco/costIndexes/bldIndexHist.asp> (5 December 2003).

ESRI Glossary (2003) *Glossary of GIS Terms*, <www.esri.com/library/glossary/glossary.html> (5 December 2003).

FFC (2002) *Learning from Our Buildings: A State-of-the-Practice Summary of Post-Occupancy Evaluation*, Federal Facilities Council, Washington, DC, <books.nap.edu/books/0309076110/html/index.html> (5 December 2003).

FHWA (1999) *Asset Management Primer*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, <www.fhwa.dot.gov/infrastructure/asstmgmt/amprimer.pdf> (5 December 2003).

FHWA (2000) *Primer: GASB 34*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, <199.79.179.19/OLPFiles/FHWA/010019.pdf> (8 December 2003).

FHWA (2001) *Data Integration Primer*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, <199.79.179.19/OLPFiles/FHWA/010393.pdf> (5 December 2003).

FHWA (2001a), *Highway Economic Requirements System State Version, (HERS-ST),* Office of Asset Management**,** Federal Highway Administration, US Department of Transportation, <wwwcf.fhwa.dot.gov/infrastructure/asstmgmt/hersindex.htm> (5 December 2003).

FHWA (2002) *Highway Economic Requirements System (HERS) V2.0: Users Guide*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, <wwwcf.fhwa.dot.gov/infrastructure/asstmgmt/hersdoc.htm> (5 December 2003).

FHWA (2002a) *Life-Cycle Cost Analysis Primer*, Office of Asset Management, Federal Highway Administration, US Department of Transportation, <www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.htm> (5 December 2003).

FHWA (2003) Office of Asset Management, Federal Highway Administration, US Department of Transportation, <www.fhwa.dot.gov/infrastructure/asstmgmt/assetman.htm> (5 December 2003).

Frangopol D.M., Lin K.Y. and Estes A.C. (1997) Life-cycle cost design of deteriorating structures, *ASCE J. of Struct. Engrg*., Vol. 123, No. 10, 1390-1401.

GASB (2001) *Basic Financial Statements—and Management's Discussion and Analysis—for State and Local Governments*, Governmental Accounting Standards Board, Norwalk, CT.

GASB (2002) Governmental Accounting Standards Board <http://www.gasb.org/> (5 December 2003).

GASB (2003) <www.gasb.org/repmodel/index.html> (5 December 2003).

GITA (2001) *The Geospatial Technology Report 2001*, Geospatial Information and Technology Association, Aurora, CO.

GITA (2003) Geospatial Information and Technology Association, <www.gita.org/> (5 December 2003).

Guide (2003) *National Guide to Sustainable Municipal Infrastructure* <www.infraguide.gc.ca> (5 December 2003).

HAPM (1995) *LifeSpans of Building Components*, Technical Note 6, Housing Association Property Mutual, June, 1995, London, <www.hapm.co.uk> (5 December 2003).

Hassanain M.A. (2002), *Integrated Systems for Maintenance Management*, Ph.D. Thesis, University of British Columbia, Vancouver, BC, 132p.

ICP (2003) Infrastructure Canada Program <www.infrastructurecanada.gc.ca/index_e.shtml> (5 December 2003)

IIMM (2000) *International Infrastructure Management Manual,* Institute of Public Works Engineering Australia, Sydney, <www.ipwea.org.au/members/documents/#10> (21 March 2004).

ISO 156861 (2000) *ISO 156861-1: 2000 Buildings and constructed assets -- Service life planning -- Part 1: General principles*, International Organization for Standardization, Geneva.

Kleiner Y. (2001) Scheduling inspection and renewal of large infrastructure assets, *Journal of Infrastructure Systems*, 7, (4), pp. 136-143, <irc.nrc-cnrc.gc.ca/fulltext/nrcc44298> (21 March 2004).

Kleiner Y., Adams, B.J. and Rogers J.S. (2001) Water distribution network renewal planning, *Journal of Computing in Civil Engineering,* 15, (1), Jan., pp. 15-26.

Kyle B.R., Lounis Z. and Vanier D.J. (2002) Multi-objective optimisation of asset maintenance management, *Ninth International Conference on Computing in Civil and Building Engineering*, April 3-5, 2002, Taipei, Taiwan, pp. 701-706.

Lemer A.C. (1998) Progress Toward Integrated Infrastructure-Assets-Management Systems: GIS and Beyond, *Innovations in Urban Infrastructure Seminar of the APWA International Public Works Congress*, Las Vegas, Nevada, pp. 7-24, <www.nrc.ca/irc/uir/apwa/apwa98> (5 December 2003).

Lounis Z., Vanier D.J., Lacasse M.A. and Kyle B.R. (1998) Effective Decision-Making Tools for Roofing Maintenance Management, *First International Conference on New Information Technologies in Civil Engineering*, Montreal PQ, Oct., pp. 425-436, <irc.nrc-cnrc.gc.ca/fulltext/nrcc42831.pdf> (5 March 2004).

MIDS (2003) Municipal Infrastructure Data Standard <www.tricom.org/mids/index.asp> (1 March 2004).

MIDS (2003a) *CAD Standard Reference Manual*, Tri-Committee for the Utilization of IT in Public Works, <www.tricom.org/files/cad/cad_manual.pdf> (5 December 2003).

MIIP (2003) Municipal Infrastructure Investment Planning Project <www.nrc.ca/irc/uir/miip> (5 December 2003).

MIMS (2003) Municipal Infrastructure Management System <www.albertamims.org>(5 December 2003).

Moser K. and Edvardsen C. (2002) Engineering Design Methods for Service Life Prediction, *9th International conference on the Durability of Building Materials and Components*, Brisbane, Australia, Paper 222, pp. 1-10.

MPMP (2003) Municipal Performance Measurement Program <www.mah.gov.on.ca/userfiles/HTML/nts_1_5600_1.html> (5 December 2003).

MRUTC (2002) *Synthesis of National Efforts in Transportation Asset Management*, Midwest Regional University Transportation Center, University of Wisconsin, Project 0092-01-10, <www.mrutc.org/research/0101/report0101.pdf> (5 December 2003).

NACUBO (1991) *Managing the Facilities Portfolio*, National Association of College and University Business Officers, Washington, DC, 100p.

NACUBO (2003) National Association of College and University Business Officers <www.nacubo.org> (5 December 2003).

OMBI (2003) Ontario Municipal CAO's (Chief Administrative Officer's) Benchmarking Initiative, <www.caobenchmarking.ca/index.asp> (8 December 2003).

Ottawa (2002) *City of Ottawa Long Range Financial Plan: First Steps* <ottawa.ca/inside_govt/budget/budget_2003/lrfp/Full_LRFP_Report_en.pdf> (8 December 2003).

Ottawa (2003) City of Ottawa <www.ottawa.ca> (5 December 2003).

RILEM (1989) *Systematic Methodology for Service Life Prediction of Building Materials and Components,* RILEM - Technical recommendation PSL 1, Paris.

RSMeans (2002) R.S. Means Company Inc., <www.rsmeans.com> (5 December 2003).

Rush S.C. and Johnson S.L. (1988), *The Decaying American Campus: A Ticking Time Bomb*, (The Association of Higher Education Facilities Officers (APPA), Washington, D.C.

Saaty T.L. and Vargas L.G. (2000) Models, Methods, Concepts & Applications of the Analytic Hierarchy Process, Kluwer Academic Publishers, Boston, MA, 333p.

Sarshar M., Finnemore M., Haigh R. and Goulding J. (1999) Spice: Is a Capability Maturity Model Applicable in the Construction Industry?, *Durability of Building Materials and Components 8*. Eds. M.A. Lacasse and D.J. Vanier, Institute for Research in Construction, Ottawa, Canada, Vol 4, pp. 2836-2843.

Shahin M.Y. (1992) 20 Years Experience in the PAVER Pavement Management System: Development and Implementation, *Pavement Management Implementation,* F.B. Holt and W.L. Gramling, editors, ASTM, West Conshohocken, PA.

SSMIC (2003) Sault Ste. Marie Innovation Centre <www.ssmic.com/pdf/SSMIC_IGS_White_Paper_V1.0.pdf> (5 December 2003).

TAC (1999) *Primer on Highway Asset Management*, Transportation Association of Canada, Ottawa, ON, 26p.

TAC (2003) Transportation Association of Canada, <www.tac-atc.ca> (5 December 2003).

TAC (2003a) Transportation Association of Canada, <www.tac-atc.ca/english/MCdbase/documentinventory.pdf> (5 December 2003).

TAC (2004) Transportation Association of Canada, Personal Communication, 6 Feb 2004.

TC (2003) Transport Canada, <www.tc.gc.ca/> (5 December 2003).

Vanier D.J. (2000) Advanced Asset Management: Tools And Techniques, NRCC/CPWA/IPWEA Seminar Series, *Innovations in Urban Infrastructure*, Louisville, KY, pp. 39-57, <www.nrc.ca/irc/fulltext/nrcc44299.pdf> (5 December 2003).

Vanier D.J. (2001) Asset Management: A to Z, NRCC/CPWA/IPWEA Seminar Series, *Innovations in Urban Infrastructure*, Philadelphia, PA, pp. 1-16, September 09, <www.nrc.ca/irc/fulltext/nrcc45163> (5 December 2003).

Vanier D.J. and Rahman, S. (2004) MIIP Report: Survey on Municipal Infrastructure Assets <www.nrc.ca/irc/uir/miip> (5 May 2004).

Victoria (1998) *Facing the Renewal Challenge: Victorian Local Government Infrastructure Study*, Department of Infrastructure, State Government of Victoria, Australia, ISBN: 0 7311 5240 9.

Victoria (2004) *Sustaining Local Assets: Local Government Asset Management Policy Statement*, Department of Victorian Communities, State Government of Victoria, Australia, <www.doi.vic.gov.au/doi/internet/localgov.nsf/headingpagesdisplay/local+government+publications> (21 March 2004).

WIN (2003a) *Clean and Safe Water for the 21st Century: A Renewed National Commitment to Water and Wastewater Infrastructure*, Water Infrastructure Network, <www.amsa-cleanwater.org/advocacy/winreport/winreport2000.pdf> (5 December 2003).

WIN (2003) Water Infrastructure Network, <www.win-water.org/> (5 December 2003).

Winnipeg (2000) *Strategic Infrastructure Reinvestment Policy, Implementation Committee Report*, May 26/2000, City of Winnipeg. <www.winnipeg.ca/cao/reports/sirp.stm> (8 December 2003).

Winnipeg (2003) <www.winnipeg.ca/> (8 December 2003).

Zhao J.Q., McDonald S.E. and Kleiner Y. (2001) *Guidelines for Condition Assessment and Rehabilitation of Large Sewers*, Institute for Research in Construction, National Research Council Canada, pp. 78, Ottawa, ON, <www.nrc.ca/irc/fulltext/nrcc45130> (8 December 2003).

Appendix A: Glossary of Related Terms

(Items that are **bolded** are defined elsewhere in the glossary)

(When the definition of a term is from an existing manual, guideline or standard, the source is cited in the definition of the term. MIIP variations to text are shown within [square bracket]).

Accumulated deficit is the cost of **maintenance** (and *not* **capital renewal**) to bring the **asset** to its original potential that has been postponed or phased. This term is synonymous with **maintenance backlog** and **deferred maintenance**.

Appreciated historical value of an **asset** is the **historical value** calculated in constant dollars, by taking into account annual inflation or deflation. The Engineering News Record has records of these values back to 1915 (ENR 2000).

Assets are defined as a physical component of a facility that has value, enable services to be provided, and has an **economic service life** of greater than 12 months (International Infrastructure Management Manual, 2000).

Asset management is a business process and decision-support framework that: (1) covers the extended **service life** of an **asset**; (2) draws from engineering as well as economics, and (3) considers a diverse range of **assets**.

Additional Definition: **Asset management** is the combination of management, financial, economic, engineering, and other practices applied to physical **assets** with the objective of providing the required **level of service** in the most cost-effective manner (International Infrastructure Management Manual, 2000).

Asset Manager is responsible to ensure the corporate **asset management** strategic policies, goals and objectives are met. The **asset manager** is responsible for the development and implementation of the **asset** plans and programs including their acquisition, operation, **maintenance**, rehabilitation and replacement. It is the **asset manager's** responsibility to maximize the effect of **asset** expenditures as well as to maximize the value of their **assets** over the **assets' service life**. The **asset manager** is also responsible for developing performance-monitoring techniques to ensure the required **levels of service** are delivered over the **service life** of the **asset**.

Benchmark is a point of reference from which measurements may be made by: something that serves as a standard by which others may be measured or judged or is a standardized problem or test that serves as a basis for evaluation or comparison (Merriam Webster).

Benefit-cost (B/C) analysis is the sum of the **present values** of all benefits (including residual value, if any) over a specified period, or the life cycle [**service life**], of the **asset** or facility, divided by the sum of the **present value** of all costs (International Infrastructure Management Manual, 2000).

Capital costs are those costs incurred to acquire, construct, or improve **assets** including the directly related planning, engineering, legal, or borrowing costs.

Capital expenditure (CAPEX) is an expenditure used to create new **assets** or to increase the capacity of existing **assets** beyond their original design capacity or service potential. **CAPEX** increases the value of **asset** stock (International Infrastructure Management Manual, 2000).

Capital lease (as opposed to **Operating lease**) as defined by the CICA Section 3065:

1. There is reasonable assurance the lessee will obtain ownership by the end of the lease when the terms result in ownership transfer, or there is a bargain purchase option.
2. The lease term is major portion (usually 75% or more) of the **asset's economic [service] life**.
3. The **present value** of the minimum lease payments is substantially all (usually 90% or more) of the cost, or fair value at inception.

Capital renewal replaces an **asset** at the end of its **service life** or because of economic, obsolescence, modernization or compatibility issues.

Capital replacement value (CRV) – see **current replacement value** (CRV).

Condition assessment is the process for evaluating the current condition of an **asset** and assigning a condition rating to that **asset**.

Condition assessment surveys (CAS) are **inspections** used to assess the condition of an **asset**; this term is used synonymously with technical audit. In many systems, the CAS provides a **facility condition index (FCI)** related to the cost of required repairs or a **technical condition index** related to the extent of the physical damage to the **asset**.

Condition based maintenance is a **maintenance** concept whereby **maintenance** tasks are identified by the collection and analysis of information relating to **asset** condition.

Condition monitoring is continuous or periodic **inspection**, and the interpretation of the resultant data, to indicate the condition of a specific **asset** so as to determine the need for **maintenance** or **capital renewal** action.

Current replacement value (CRV) is the cost of replacing an **asset** in current dollars.

Database (DB) is one or more large structured sets of persistent data, usually associated with software to update and query the data. A **simple database** might be a single file containing many records, each of which contains the same set of fields where each field is a certain fixed width. (hostingworks.com/support/dict.phtml?foldoc=database) (See **simple**, **relational** and **object-oriented database**).

Decision support system (DSS) is a software tool providing decision-makers with useful summaries and analysis of data.

Deferred maintenance is the cost of **maintenance** (and *not* **capital renewal**) to bring the **asset** to its original potential that has been postponed or phased. This term is synonymous with **maintenance backlog**.

Deprival cost is the "cost that would be incurred by an entity if it were *deprived* of an **asset** and was required to continue delivering programs/services using the **asset**. The value is measured by the *replacement cost* of the benefits currently embodied in the **asset**. **Deprival value** can also represent an *opportunity value* i.e. the cost avoided as a result of having control of an **asset**" (ANAO 1996, p. 68). This term is used predominantly in Australia.

Deterioration is a process by which there is a loss of **asset** performance due to loss of strength, effects of usage, environmental exposure or passage of time.

Discount rate is an agreed upon/accepted factor to reflect the time-value of money. The **discount rate** in public organizations is usually based on the organization's cost of raising capital. The **discount rate** in the private sector is normally defined as the financial opportunity of one investment when compared to "**risk**-free" annual return on another.

Additional Definition: **Discount rate** is an agreed upon/accepted factor to reflect the time-value of money. When comparing economic activities that involve streams of costs/benefits accruing at different times, the discount factor is used to "normalize" these costs/benefits. There are two types of **discount rates**: financial and social. The financial discount rate is used to reflect the time-value of money as compared to a benchmark opportunity cost of capital. The financial **discount rate** in public organizations is often based on the organization's cost of raising capital. The financial **discount rate** in the private sector is often based on "**risk**-free" annual return rate such as a commercial bank certificate of deposit or a government treasury bond. The social **discount rate** is used to reflect social values and preferences in comparing or measuring economic activities involving large public assets (e.g., **infrastructure**) with cost/benefit streams spanning very long time periods. A higher social **discount rate** reflects a greater tendency to defer public costs to future generations.

Economic service life is that time after which it is more economical to replace an **asset** than it is to continue to maintain it.

Facility condition index (FCI) is the ratio of **deferred maintenance** to **current replacement value** (CRV). FCI = Deferred Maintenance / CRV

Geographic information system (GIS) is a "collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information" (ESRI Glossary, 2003).

Historical value is the original "book value" of the **asset**. This includes the original acquisition costs, purchase price, taxes, and any other costs necessary to make the **asset** ready for its intended use.

Inflation rate is the percentage change in the price index from the preceding period.

Infrastructure is the physical network of **assets** that provides services to the general public, such as transportation, utilities (water, gas, electricity), energy, telecommunications, waste disposal, recreation and accommodation.

Inspections are the **planned** or **unplanned** monitoring and recording of the performance or condition of an **asset**.

Legacy system is an older computer system or application program that an agency continues to use.

Level of service is a qualitative or quantitative measure of how well or poorly a service is provided.

Life cycle cost (LCC) is the total cost, in **present value** or annual value, required to maintain an **asset** in full performance for its **service life**. This can include the **operating**, capital and operating leases, **maintenance**, user, and socio-economic costs.

Life cycle cost analysis (LCCA) is a process for evaluating the total economic value of an **asset** by analyzing initial costs and discounted future costs, such as **operating**, **maintenance**, user and socio-economic costs over the **service life** of the **asset**.

Maintenance covers a broad range of **planned** or **unplanned** activities for preserving the **asset** in its original condition and for the purpose for which it was originally intended. **Maintenance** generally consists of: (1) **inspections,** (2) **preventive maintenance,** (3) **repairs**, and (4) **rehabilitation**.

Maintenance backlog is the cost of **maintenance** (and *not* **capital renewal**) to bring the **asset** to its original potential that has been postponed or phased for future action. This term is synonymous with **deferred maintenance**.

Market value is the value of the **asset** if it were sold on the open market today.

Municipal infrastructure includes those **assets** normally managed by municipalities and normally includes buried utilities, roads, transit systems, bridges, buildings, recreational facilities, treatment plants, and parks. It may also include various types of buildings.

Multi-objective maintenance optimization is a **decision-support tool** based upon compromise programming methods where the simultaneous satisfaction of conflicting objectives is considered: for example, minimization of **maintenance** and repair costs, maximization of network performance, and minimization of **risk** of failure.

Object oriented database (OOB) is a database in an object-oriented programming environment. Data are stored as classes of objects and as a set of operations or methods, which can be used on these data.

Operating costs are the direct costs of maintaining and operating **assets** including labour, **maintenance**, administrative, fuel, or insurance. Some organizations include **operating leases** as operational costs.

Operating Lease is where an **asset** is leased to provide temporary services and does not meet the defined criteria for a **capital lease**.

Performance indicator (PI) is a qualitative or quantitative measure of a service or activity used to compare actual performance against a standard or other target. **Performance indicators** commonly relate to statutory limits, safety, responsiveness, cost, comfort, **asset** performance, reliability, efficiency, environmental protection, and customer satisfaction (International Infrastructure Management Manual, 2000).

Planned maintenance consists of **maintenance** that can be predicted and is implemented when resources are become available.

Planning horizon is the finite time horizon used for calculating future.

- **operational** planning horizon represents the current budget years of the organization, normally within two years.
- **tactical** planning horizon represents the medium term planning range of the organization, normally from two to five years.
- **strategic** planning horizon represents the long term planning range of the organization, normally beyond the five-year time frame.

Present Value (PV) of an **asset** consists of its initial costs (C_t) along with all future **maintenance** and **repair** costs (C_t) for a specific length of study (N) and a specific **discount rate** (i) brought to present dollars (ASTM E917 1994).

$$PV = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t}$$

Preventive maintenance is the planned **inspection** of an **asset** to ensure the **asset** will continue to perform its intended functions throughout its **service life** (e.g. obstructions are removed and depleted protection fluids are replenished).

Probabilistic models are mathematical descriptions of uncertain situations. The **probability model** assigns possible outcomes to encode our knowledge or belief about the collective "likelihood" of the outcome.

Rehabilitation replaces one or more major components of an **asset** when the **asset** has reached the end of its **service life**.

Relational database management system (RDBMS) is a database based on the model developed by E.F. Codd (1990). A RDBMS is a "method of structuring data as collections of tables that are logically associated to each other by shared attributes. Any data element can be found in a relation by knowing the name of the table, the attribute (column) name, and the value of the primary key" (ESRI Glossary, 2003).

Reliability centred maintenance (RCM) is a process for optimizing **maintenance** based on the reliability characteristics of the **asset** (International Infrastructure Management Manual, 2000).

Repairs involve restoring an **asset** to full operation after it has failed to perform some or all of its function. **Repairs** do not result in a significant extension of the expected **service life** of the **asset**.

Residual value is the market or recoverable value of an **asset** (after expenses) that would be realized from the disposal of an **asset** at the end of its **service life**.

Risk is defined as the probability that an event will take place under specified conditions. **Risk** is calculated as the multiplication of two factors: the probability that an adverse event will occur and the consequences of that adverse event.

Risk management is the process of identifying, evaluating, selecting, and implementing actions to reduce **risk**. The goal of **risk management** is scientifically sound, cost-effective, and integrated actions that reduce or prevent **risks** while taking into account social, cultural, ethical, political, and legal considerations (See **risk**).

Salvage Value is the net value received from the recycling of materials at the end of the **service life** of an **asset**.

Service life is defined as "the actual period of time during which [the **asset**] or any of its components performs without unforeseen costs of disruption for **maintenance** and repair" (CSA 1995). The term "unforeseen" is a key word in the definition: all components and materials require planned **maintenance** and they must be maintained to ensure the **service life** is reached.

- **Economic service life** is that time after which it is more economical to replace an asset than to continue to maintain it.

- **Technical service life** is that predicted time until the asset fails to perform its intended functions.
- **Remaining service life (RSL)** is typically the remaining technical service life of a specific asset.

Simple database is a simplified data structure where each record in the database can contain data in each and every field.

Strategic plan is a plan containing the long-term goals and strategies of an organization. Strategic plans have a strong external focus, cover major portions of the organization and identify major targets, actions and resource allocations relating to the long-term survival, value and growth of the organization (International Infrastructure Management Manual, 2000).

Structured query language (SQL) is an application program interface to a **database** permitting interactive information queries of the data and for updating the **database**. SQL is both an ANSI (American National Standards Institute) and ISO (International Organization for Standardization) standard.

Technical condition index is the condition index related to the extent of the physical damage to the **asset**.

Unplanned maintenance consists of **repairs** that could not be predicted, and are repaired as and when the **asset** fails to perform its functions.

Value engineering (VE) is a function-oriented, systematic team approach used to analyze and improve value in a product, facility, design, system, or service. It comprises methodologies for solving problems and/or reducing costs while improving performance/quality requirements. Value engineering increases the customer satisfaction and adds value to the investment.

Weighted factor method is a decision support tool to assist users quantify, compare, and rank alternatives. In this method a number of significant characteristics of the **asset** or service can be selected and assigned weighed factors according to their importance to the organization. The user can then rate how the **asset** performs according to each of these characteristics. Results are obtained by multiplying the scores from the assigned weighed factors of each significant characteristic by the user-assigned ratings and then by adding the results. This technique can also be extended to include different characteristic weightings and different ratings from any number of individuals.

Appendix B: MIIP Abbreviations

AASHTO	**American Association of State Highway Officials**
ADM	Accumulated Deferred Maintenance
AHP	Analytical Hierarchy Process
AIJ	Architectural Institute of Japan
AMQI	Asset Management Quarterly International
ANAO	Australian National Audit Office
APWA	American Public Works Association
ASCE	American Society of Civil Engineers
ASTM	American Society of Testing and Materials
B/C	**Benefit / Cost**
CAD	**Computer Aided Design**
CAPEX	Capital Expenditure
CAS	Condition Assessment Survey
CAUBO	Canadian Association of University Business Officers
CICA	Canadian Institute of Chartered Accountants
CMHC	Canada Mortgage and Housing Corporation
CMMS	Computerized Maintenance and Management System
CRV	Current Replacement Value
CSA	Canadian Standard Association
CSCE	Canadian Society of Civil Engineers
CSIF	Canada Strategic Infrastructure Fund
DBMS	**Database Management System**
DM	Deferred Maintenance
DND	Department of National Defence
DSS	Decision Support System
ENR	**Engineering News Record**
FCI	**Facility Condition Index**
FCM	Federation of Canadian Municipalities
FFC	Federal Facilities Council
FHWA	Federal Highway Administration

GASB	**Governmental Accounting Standards Board**
GIS	Geographical Information System
GITA	Geospatial Information and Technology Association
GPS	Global Positioning System
HAPM	**Housing Association Property Mutual**
IBM	**International Business Machines Corporation**
ICP	Infrastructure Canada Program
IGS	Integrated Geomatics Service of Sault Ste. Marie Innovation Centre
IIMM	International Infrastructure Management Manual
IMEA	Institute for Municipal Engineering Australia
IPWEA	Institute of Public Works Engineering Australia (formerly IMEA)
IRC	Institute for Research in Construction
ISO	International Organization for Standardization
IT	Information Technology
KPI	**Key Performance Indicator**
LCC	Life cycle Costs
LCCA	Life cycle Cost Analysis
MIDS	**Municipal Infrastructure Data Standard**
MIIP	Municipal Infrastructure Investment Planning
MIMS	Municipal Infrastructure Management Systems
MMAH	Ministry of Municipal Affairs and Housing (Ontario)
MRUTC	Midwest Regional University Transportation Centre
NACUBO	**National Association of College and University Business Officers**
NIST	National Institute of Standards and Technology
NRC	National Research Council of Canada
OID	**Object Identification (Object ID)**
OMBI	Ontario Municipal CAO's Benchmarking Initiative
OODBMS	Object-oriented Database Management Systems
OTS	Off the Shelf
PDF	**Adobe's Portable Document Format**
PI	Performance Indicator
PV	Present Value

PWGSC	Public Works and Government Services Canada
RCM	**Reliability Centred Maintenance**
RSL	Remaining Service Life
SAMI	**Strategic Asset Management Integrator**
SIRP	Strategic Infrastructure Reinvestment Policy
SQL	Structured Query Language
TAC	**Transportation Association of Canada**
TC	Transport Canada
VE	**Value Engineering**

Appendix C: City of Edmonton's "Infrastructure Strategy: 2002 Update"

EDMONTON

Edmonton's

Infrastructure Strategy Overview

Leading the way.

Introduction

A city's health can be measured by the quality of its infrastructure.

These assets, developed by a municipality to provide services to citizens, include roads, sewer lines, transit, emergency response vehicles, swimming pools, parks, information technology and more. All make vital contributions to a community's quality of life. Many of Edmonton's infrastructure assets were built between 1950 and the late '70s and are now approaching the point at which significant investment is necessary to maintain existing service levels.

The challenge of deteriorating infrastructure assets is not restricted to the City of Edmonton — most major metropolitan areas in North America are dealing with similar concerns about the financial and social costs of aging infrastructure and the need for new infrastructure to accommodate growth.

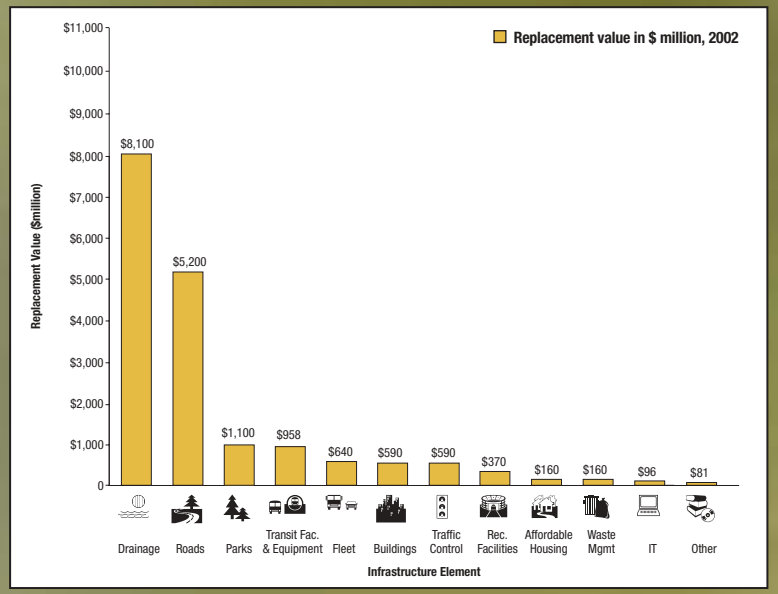
In the mid-'90s, the City saw that funding for infrastructure rehabilitation programs was shrinking relative to the increasing need for renewal and upgrading. It did not, and would not under existing circumstances, have enough money to get the job done. Edmonton has also experienced tremendous population growth and the resulting demand for new infrastructure has made it even more difficult to maintain or upgrade older infrastructure. Current estimates of the 'infrastructure gap' — the shortfall between the cost of infrastructure projects required to meet demands and the money available to pay for those projects — has been estimated at $3.2 billion over the ten-year period from 2003 to 2012.

Responding to these pressures, Edmonton developed the *Infrastructure Strategy* to more progressively manage the City's $18 billion inventory of infrastructure assets and established the Office of Infrastructure to implement the strategy.

The *Infrastructure Strategy* is the foundation of a commitment to better manage our infrastructure and associated expenses. More effective infrastructure management will strengthen the City's ability to:

- provide cost-effective municipal services;
- promote economic development;
- ensure citizen safety;
- protect the environment; and
- provide a high quality of life for Edmontonians.

Infrastructure asset value



What is infrastructure?

The City of Edmonton defines infrastructure as "all the physical assets developed and used by the City to support the community's social and economic activities." Infrastructure includes all the equipment and facilities to provide policing, fire protection, ambulance and disaster services; parks, athletic fields, recreation and cultural facilities; sewage and stormwater pipes and sewage treatment services; garbage collection and recycling; roads, bridges, sidewalks and traffic signals; buses, transit centres and the LRT; information technology to support service delivery — such as computers, network services and telephones; as well as libraries — even the books inside libraries. All these infrastructure assets combine to provide one of the highest qualities of life of any Canadian city.

Protecting existing assets

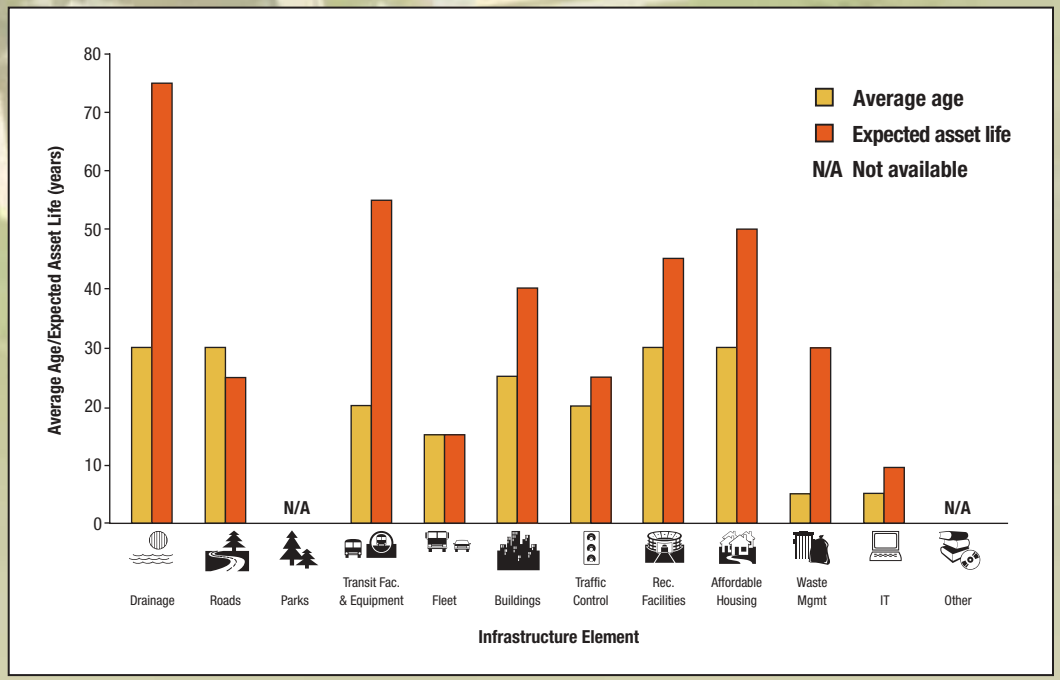
But, like a responsible homeowner, the City must undertake regular maintenance to protect its investment — and the investment of its citizens. Overall, the average age of the Edmonton's infrastructure is about 25 years and the average life expectancy of infrastructure assets is 50 years.

A majority of the City's infrastructure is in fair to good condition. Some assets, however, are in poor or critical condition and need to be upgraded in order to continue to meet the needs of Edmontonians. These ratings are based on a five-point rating system developed by the Office of Infrastructure to compare diverse infrastructure assets and are discussed more fully later in the document.

Edmonton's infrastructure assets by class

Drainage	includes sanitary, storm and combined sewers (incl. manholes, catchbasins) and wastewater treatment.
Road Right-of-Way	includes roads (arterials, collectors, local; and curb and gutter), sidewalks, bridges and auxiliary structures (such as gates, streetscapes and others).
Parkland	includes horticulture, trails, hardsurfaces, playground, sportsfields, park infrastructure and parks.
Transit Facilities and Equipment	includes Light Rail Transit (LRT) system facilities and equipment (including cars), transit centres, bus equipment and systems, trolley system.
Fleet	includes transit buses, city vehicles and shop equipment.
Buildings	includes civic offices, public works and operation facilities (e.g. yards), emergency response buildings, police buildings and libraries.
Traffic Control & Street Lighting	includes traffic signals, signs, markings, street lighting and parking metres.
Recreation Facilities	includes all major recreational facilities (e.g. arenas, leisure centres, Fort Edmonton Park) and amenities.
Affordable Housing	includes non-profit housing, community housing and senior lodges/cabins.
Waste Management Facilities	includes operation and administration facilities, transfer stations and public facilities, processing facilities and operating landfills and appurtenances.
Technology Equipment	includes servers, network, all communication equipment.
Others	includes emergency response and police equipment, and library contents and materials.

Average age and expected asset life of infrastructure

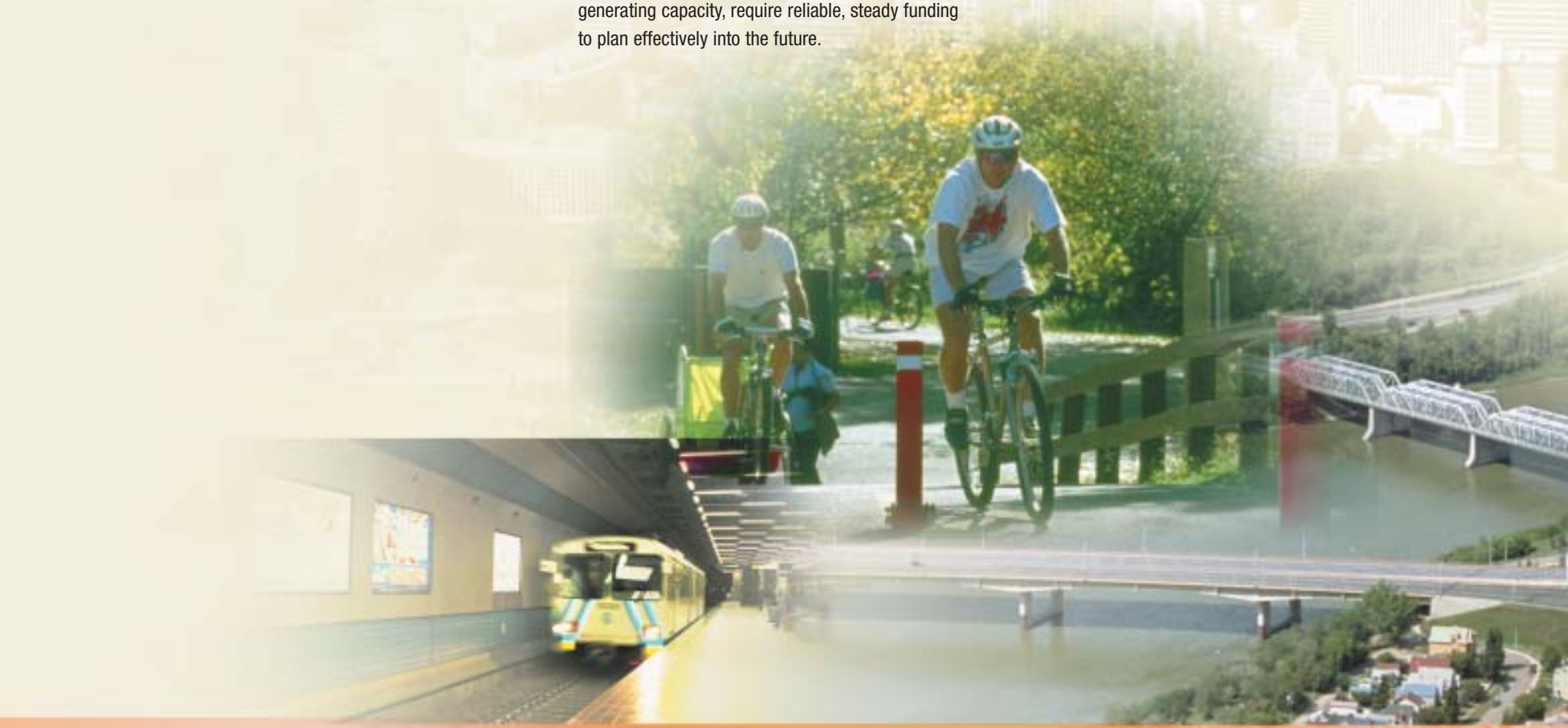


Coping with growth

In addition to coping with aging infrastructure, Edmonton has experienced rapid economic and population growth. This growth is projected to continue in coming years and will exert mounting pressure on existing infrastructure — increasing traffic, for instance, from outlying areas — and amplify the demand for new roads, sewers and recreation facilities.

Declining municipal revenues

Council has been trying to limit property tax increases for several years. The resulting revenue crunch makes it difficult for the City to make long-term plans. In addition to property taxes, an important source of funding to Alberta municipalities is the provincial government. Municipal grants have been relatively unstable in recent years, making it even more difficult for the City to plan its budget requirements. Municipalities, because of their limited revenue generating capacity, require reliable, steady funding to plan effectively into the future.



The Infrastructure Gap

"Another significant threat to the quality of life in Canada's urban areas is the erosion of city infrastructure. Until recently, the relative youth of Canadian cities meant that the pressure on Canadian governments to re-invest in infrastructure was relatively modest compared to that faced by their U.S. and European counterparts. But, it is becoming evident to most Canadians that their cities are showing distinct signs of strain. Merely maintaining existing roads, bridges, transit systems and other types of infrastructure is not enough — modernization is also required."

~ A Choice Between Reinvesting in Canada's Cities or Disinvesting in Canada's Future
TD Bank Financial Group, Special Report, April 2002

The City of Edmonton's 'infrastructure gap' is the estimated shortfall between the projected cost of infrastructure projects and the funds available to pay for those projects over a ten-year period. The City of Edmonton first identified an infrastructure gap almost a decade ago.

The infrastructure gap is growing

The current ten-year infrastructure gap for the period 2003-2012 is estimated at $3.2 billion. This gap continues to grow each year as a result of the following factors.

- The money currently available for infrastructure investment is below expert recommendations of between two and four per cent of total asset value,

which means infrastructure assets are deteriorating at a rate faster than they are being rehabilitated or replaced.

- Edmonton's continued growth requires new subdivisions, business and industrial development, roads, sewers, public transit, parks and recreation facilities, police and emergency services, all of which add to the cost of infrastructure without an equal contribution to the City's revenue.
- Inflationary increases make rehabilitation more expensive because construction costs are increasing every year. Assets also continue to deteriorate as construction or repair work is postponed, which means more extensive rehabilitation is required as time passes.
- New environmental and engineering standards — such as more stringent requirements to protect water resources — make renewal and upgrading programs even more necessary.

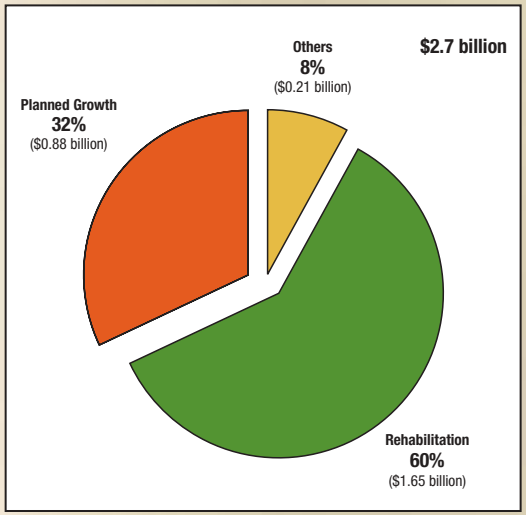
Infrastructure investment plan

The City of Edmonton has three key categories in its infrastructure investment plan.

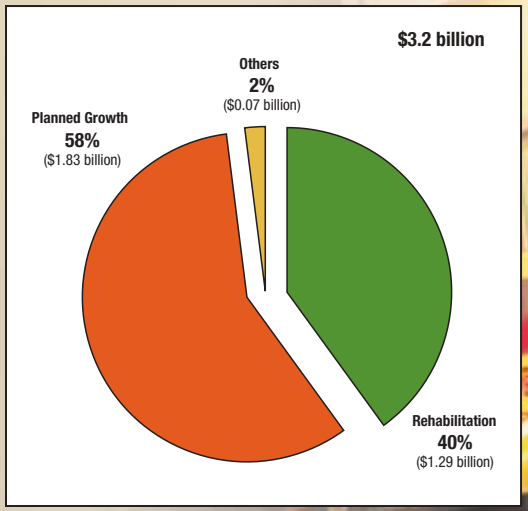
- **Infrastructure and physical environment** — investment in rehabilitation, replacement and environmental expenditures.
- **Planned growth** — investment in new infrastructure or expansion of existing infrastructure to support growth.
- **Other** — investment in economic development, organizational effectiveness and regional initiatives.

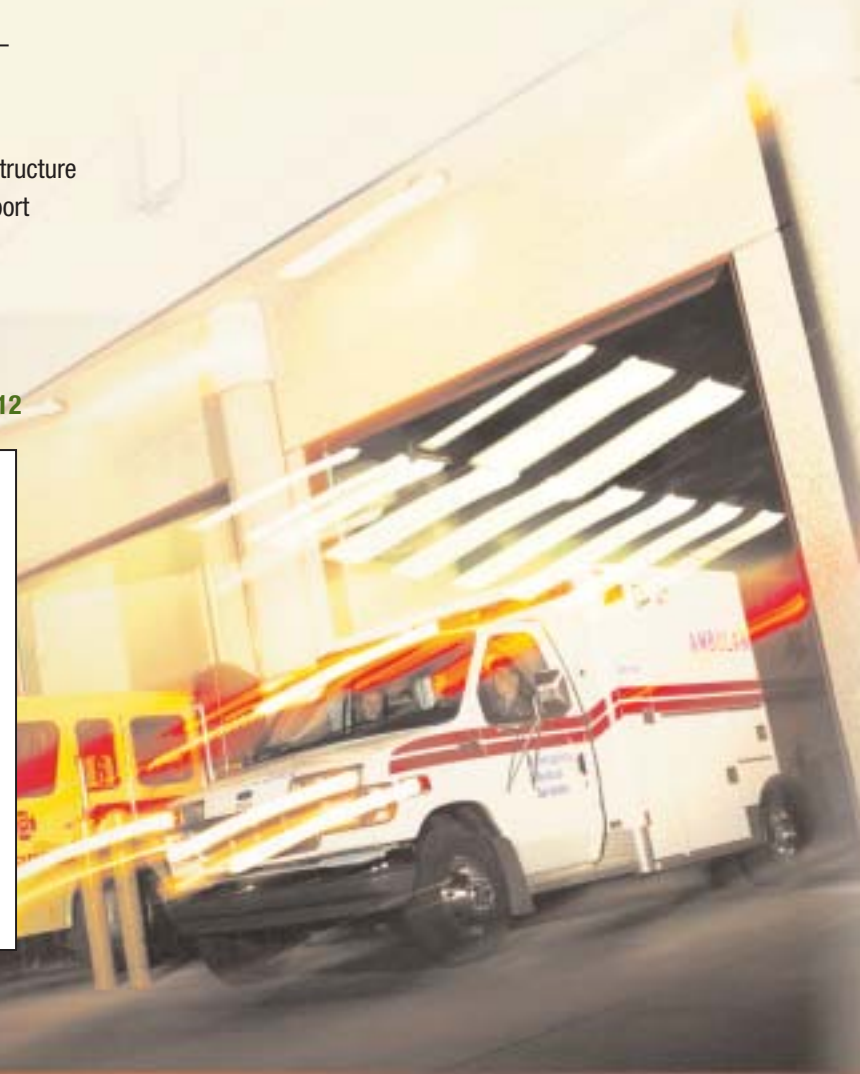
The most significant unfunded areas that comprise the infrastructure gap — those projects for which funding does not exist — through to 2012 are illustrated in the second pie chart below.

Percentage of funded City projects, 2003-2012



Percentage of unfunded City projects, 2003-2012





Maintaining existing infrastructure

Municipal infrastructure experts in North America advise that annual investment for existing infrastructure should be between two and four per cent of the total replacement value of infrastructure assets. Using this guideline, Edmonton should invest no less than $360 million — two per cent of $18 billion — every year in rehabilitation and replacement programs. Over the next 10 years, the City has estimated it will be able to spend, on average, approximately $165 million annually, which is less than half the recommended minimum. Current funding is insufficient to maintain existing infrastructure.

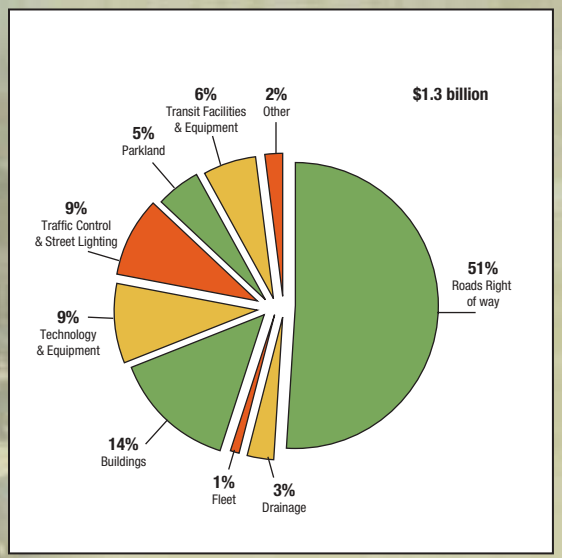
Given the forecasted spending, it would take 14 years to rehabilitate or replace just the infrastructure assets that had a "poor" or "critical" physical condition rating in 2002 alone. Obviously, some other infrastructure assets now rated "fair" or "good" would deteriorate over that period and also require renewal. That further deterioration would increase investment requirements but would be unfunded under current projections.

Addressing growth

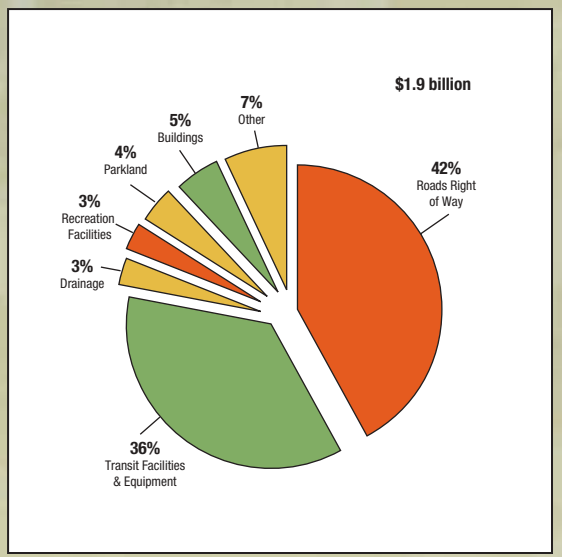
Population growth in Edmonton is approaching the record levels of the late 1970s and early '80s and, in 2002, accounted for almost 9,000 new homes being built.

Population growth, mostly due to in-migration, puts pressure on the City to invest more money in new or expanded infrastructure. Development causes Edmonton to grow in many directions. New roads and drainage in local subdivisions are funded by developers and included in the purchase price charged to new home buyers. Local roads and sewers, however, must be linked to major sewer trunks and arterial roads — which are partly funded by the developer — not to mention the costs of building new recreation facilities, police and emergency response stations, libraries and other infrastructure. This growth stretches Edmonton's capacity for infrastructure investment.

Unfunded infrastructure projects, 2003-2012
Infrastructure and physical environment



Unfunded infrastructure projects, 2003-2012
Planned growth



Growth projects

The vast majority of the City's $1.9 billion in unfunded planned growth capital projects are in two infrastructure classes: roads and transit

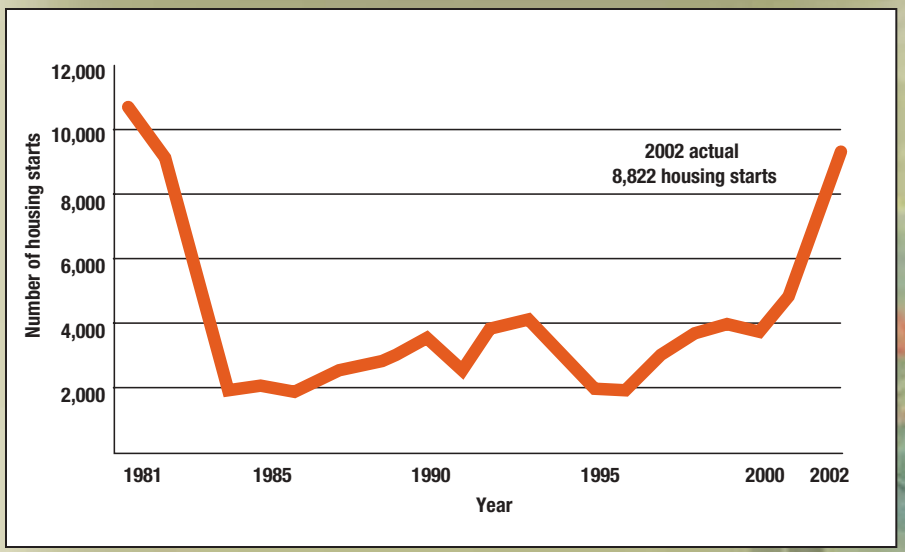
It is anticipated that the City will need to spend almost $800 million on roads by 2012, including projects like the Yellowhead Trail and 156th Street interchange, and the Whitemud Freeway and 34th Street interchange, other ring road projects, street lighting and traffic control systems.

Transit system projects are expected to cost approximately $660 million through to 2012, including new buses, transit facilities and the proposed southern extension of the LRT from the University of Alberta to Heritage Mall. If the LRT project is approved in its entirety, it will cost over $500 million.

Other unfunded, planned growth capital projects include parks, recreation and cultural facilities, low cost housing, a new police station and training facility, and library facilities.

It is clear that the City cannot sustain the delivery of municipal services at current levels without addressing the inadequate funding available for investment in infrastructure assets or to build new roads, sewers, transit centres and recreation facilities. Generating additional revenue through mechanisms that are acceptable to taxpayers must be the City's first priority if services are to remain unchanged.

Housing starts, 1981-2002



Edmonton's *Infrastructure Strategy* and the Office of Infrastructure

"Urban economies and society literally depend upon the infrastructure on which they are built. The availability and functionality of infrastructure will determine an urban area's attractiveness and growth potential. The ability to develop and maintain infrastructure at a reasonable standard and within a competitive fiscal environment is key to an urban municipality's future."

~ Edmonton's *Infrastructure Strategy*, June 1998

Infrastructure management is comparatively new and relatively few municipalities have strategies to deal with the issues of infrastructure management. Edmonton took an innovative approach to infrastructure management in 1998 with the development of the *Infrastructure Strategy*, and built upon that initiative by creating the Office of Infrastructure in 2000. Edmonton has since become recognized as a leader among Canadian cities.

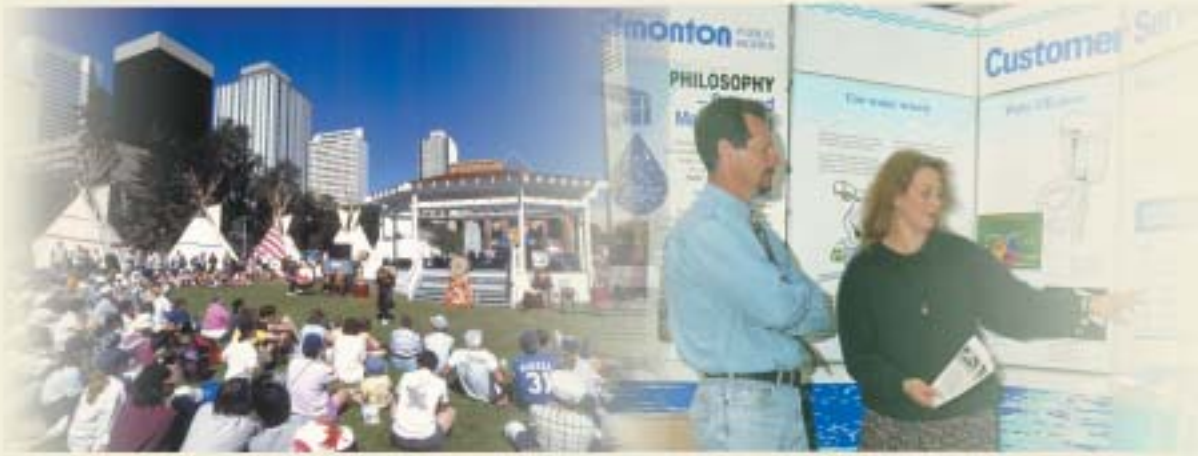
The *Infrastructure Strategy* will help Edmonton balance competing needs for rehabilitation and growth. Fluctuations in municipal funding from the provincial and federal governments, increasing demand from citizens for services, and a limited ability to generate revenue, all emphasize the need to effectively manage municipal infrastructure assets.

The *Infrastructure Strategy* promotes innovative ways to maximize the benefit of available funding and to ensure that:

- the City's existing infrastructure is in a good state of repair;
- rehabilitation and new development programs are adequately funded; and
- infrastructure programs are funded as efficiently and effectively as possible.

The Office of Infrastructure is responsible to implement and monitor the *Infrastructure Strategy*. Currently, the Office is working to define issues related to the infrastructure gap and pioneering innovative tactics to address it. Through its involvement with various provincial and national groups including the joint effort of the Federation of Canadian Municipalities and the National Research Council to develop a National Guide to Sustainable Municipal Infrastructure, Edmonton is gaining and sharing knowledge with other cities also grappling with their own infrastructure challenges.

Since 2000, the Office of Infrastructure has achieved significant progress toward meeting the infrastructure challenge. The Office of Infrastructure is leading the effort to develop new and innovative management tools to ensure that the limited funding available is invested wisely and that taxpayers receive the best possible value for their tax dollar.



Developing innovative tools

Rating System

Each type of infrastructure has its own maintenance, rehabilitation and replacement requirements. The Office of Infrastructure has developed a standardized rating system to evaluate the state and condition of existing infrastructure assets. The system evaluates infrastructure according to three key criteria:

- physical condition;
- demand/capacity —ability of infrastructure to meet demand; and
- functionality —ability to deliver services and program needs.

Every infrastructure class and individual assets within each class are rated according to these criteria. Ratings A and B signify Very Good and Good, respectively; C is Fair; and ratings D and F are Poor and Critical. Infrastructure with a D or F rating is in unacceptable condition, not performing to its designed purpose or not meeting program and service delivery needs — or some combination of the three.

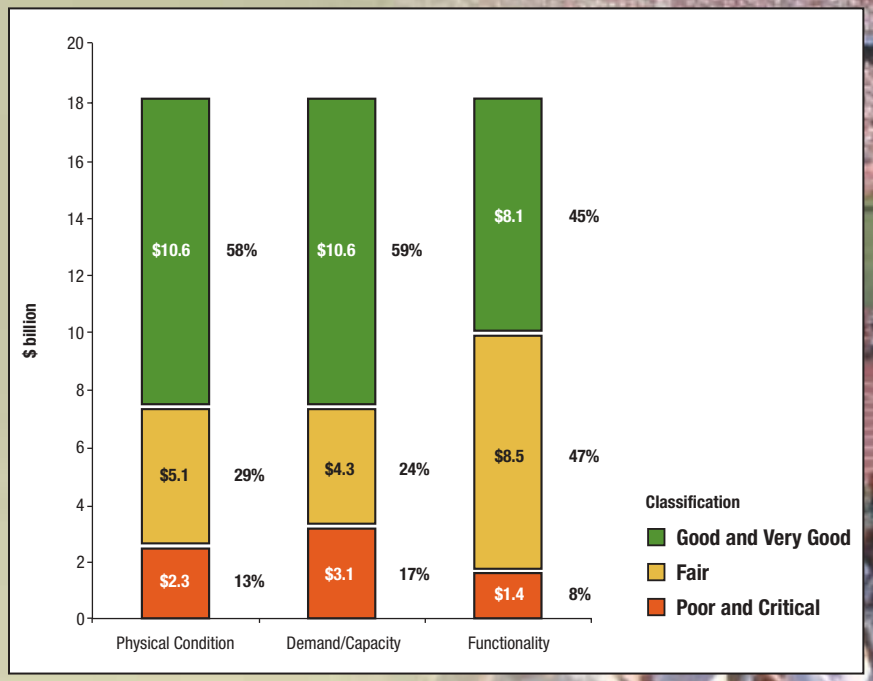
Although the quality of available data varies and requires some assumptions in the assessment, this new rating system provides a useful perspective of the state and condition of the City's infrastructure.

Continued improvements to data collection and analysis will generate more consistent and accurate data, which will better enable the City to make informed decisions regarding infrastructure renewal, replacement or expansion.

The new rating system makes it easier to compare the condition of different classes of infrastructure — roads to drainage, or parks to information technology — something that was difficult to do in the past. This improved comparison provides a valuable tool to support improved decision-making. The rating system identifies infrastructure most in need of repair and,

This chart indicates the magnitude of investment required in each infrastructure category for existing assets. However, they should not be added together to determine a cumulative investment requirement. For example, if an asset is in poor physical condition, it may not have a correspondingly poor rating in the demand/capacity or functionality criteria. It is also possible that an investment in one category may resolve the issues in the other two categories without requiring additional investment.

Overall status of the City's infrastructure



consequently, which capital projects are most urgently needed. This information is then used to guide the budget planning process.

The following areas have been identified as having high investment requirements:

- roads
- street lighting
- drainage systems
- buildings; and
- LRT trains and buses.

Risk Assessment

The Office of Infrastructure has developed a risk assessment process to assess the scale and likelihood of infrastructure failure related to current funding shortfalls. Risk assessment helps identify a prudent course of action and provides decision-makers with a tool to determine the potential impacts of not investing in specific infrastructure projects. Risk assessment also provides a guide for budget and investment planning. The Office of Infrastructure anticipates that a risk assessment will be completed for most of the infrastructure classes in 2003.

Life Cycle Costing

Life cycle costing enables the comparison not only of construction and material costs — such as asphalt against concrete — but it also enables a comparison of future investment requirements and the total cost of operating, maintaining, rehabilitating and replacing an asset. This tool will enhance financial planning and help decision-makers to select the most cost-effective infrastructure. Funding decisions can then be made with a view to the total cost of an asset over the course of its life expectancy rather than restricting that decision to initial construction costs. The Office of Infrastructure is promoting the use of life cycle costing in infrastructure management.

Developing a team approach

Edmonton has developed a strategic team approach to infrastructure management and to finding the best solutions to the challenges presented by the infrastructure gap. The Office of Infrastructure and interdepartmental teams — consisting of managers from key civic departments — work cooperatively to implement the *Infrastructure Strategy*. Individual departments work with the Office to develop new tools and processes — such as the rating system, risk assessment and life cycle costing — and to assess and report on the state and condition of infrastructure assets.

The City also receives input from the Infrastructure Technical Advisory Committee, a group of technical stakeholders with expertise in infrastructure design, development and management. Representing a broad cross-section of professional organizations, business associations and community groups, this committee represents the first phase of a public/stakeholder involvement process and provides valuable advice to the City as it implements the *Infrastructure Strategy*.

Aligning infrastructure with corporate plans

Successful implementation of the *Infrastructure Strategy* requires integrating infrastructure issues into the City's major corporate initiatives. Infrastructure inventory, state and condition ratings, and critical need areas are considered as Edmonton develops its annual Corporate Business Plan, Long Range Financial Plan and annual budgets.

Developing and benefiting from national efforts

Over the last few years, Edmonton has participated in the development of a National Guide to Sustainable Municipal Infrastructure, sponsored by the Federation of Canadian Municipalities and the National Research Council of Canada. Working with experts from across the country, the Office of Infrastructure and other key City staff are developing strategic alliances and monitoring best practices for the management of municipal infrastructure. Edmonton will continue to provide leadership by sharing our knowledge and expertise as municipalities across Canada struggle with infrastructure issues. The City will also benefit as it receives first-hand knowledge of best practices that result from the development of the National Guide.

Alternative funding

Edmonton is exploring new ways to generate revenues to meet the mounting infrastructure challenge.

The federal and provincial governments have provided some alternative sources of infrastructure financing. The Alberta government shares gasoline tax revenues with Edmonton and Calgary, which help to address key transportation demands. The Infrastructure Canada-Alberta Program provides federal and provincial dollars to 'top up' municipal contributions to necessary infrastructure projects. Since 2000, the Infrastructure Canada-Alberta Program has allocated over $100 million of shared funding to infrastructure projects in Edmonton.

Prudent fiscal management at the municipal level has also resulted in some new funding sources. In 2003, City Council approved converting land drainage to a utility, which makes the service self-financing because any costs associated with the service are delivered on a user-pay basis. Another benefit is that the City will no longer need to incorporate drainage services in its tax-supported infrastructure capital budget projections.

The City has partnered with developers and builders to finance the construction of major sanitary sewers to support development. Sharing these costs has reduced the fiscal burden on the City and enabled development to proceed that might otherwise have been delayed.

City Council also decided to assume up to $50 million of tax-supported debt each year over five years, beginning in 2003, to pay for critical infrastructure projects that would otherwise be unfunded. Four projects were approved for tax-supported debt financing in 2003: $23 million for the Whitemud Drive and 34 Street interchange; $11.6 million to build a new police station in Mill Woods; $7.6 million for road improvements throughout the city; and, $7.8 million for road rehabilitation and new neighbourhood parks in six subdivisions. Tax-supported debt will contribute $250 million toward the $3.2 billion infrastructure gap over the next five years. An increase of one per cent in property taxes will be collected to pay for the debt.

On the horizon

Edmonton is one of Canada's leading municipalities in the implementation of advanced infrastructure management techniques. The *Infrastructure Strategy* has established the foundation for further improvement and the Office of Infrastructure — a dedicated resource — in cooperation with all the city departments, has been instrumental in that success.

The *Infrastructure Strategy* substantiates infrastructure investment requirements because it captures the City's infrastructure asset inventory and demonstrates the areas with the greatest need. Edmonton will continue to align the *Infrastructure Strategy* with corporate and departmental business plans and other key corporate initiatives, including the City's Long Range Financial Plan.

The risk assessment tool will identify the cumulative risk associated with current infrastructure investment practices that are below expert recommendations. The continued funding shortfall means that the infrastructure gap is getting larger every year, a situation that puts at risk the enviable quality of life in Edmonton. Quantifying investment requirements will enable the City to make more comprehensive comparisons among different assets and to invest available infrastructure dollars in the most urgent areas.

The total investment required to maintain all existing infrastructure assets at current or acceptable levels should also be determined. This knowledge will support sound decision-making in the future.

Failing to meet the infrastructure challenge will impede Edmonton's ability to support growth and to derive the benefits of that growth. Difficult decisions remain, particularly with respect to securing adequate funding. Edmonton will continue to negotiate with other orders of government and other municipalities to establish a more equitable position and to explore additional alternatives. The City will also explore new funding approaches and management strategies — all with the goal of effectively managing growing infrastructure requirements and decreasing the infrastructure gap.

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