Roads and Sidewalks

Priority Planning and Budgeting Process for Pavement Maintenance and Rehabilitation

This document is the sixth in a series of best practices for the design, maintenance and management of municipal roads and sidewalks. For titles of other best practices in this and other series, please refer to *www.infraguide.ca.*

National Guide to Sustainable Municipal Infrastructure

NRC·CNRC Federation of Canadian Municipalities Canada

Priority Planning and Budgeting for Pavement Maintenance and Rehabilitation

Issue No. 1.0

Publication Date: November 2003

InfraGuide – Innovations and Best Practices

Why Canada Needs InfraGuide

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

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

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

A Knowledge Network of Excellence

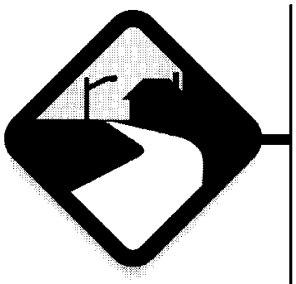
InfraGuide´s creation is made possible through $12.5 million from Infrastructure Canada, in-kind contributions from various facets of the industry, technical resources, the collaborative effort of municipal practitioners, researchers and other experts, and a host of volunteers throughout the country.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

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

Please join us.

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

The InfraGuide Best Practices Focus



Municipal Roads and Sidewalks

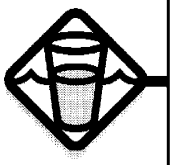
Sound decision making and preventive maintenance are essential to managing municipal pavement infrastructure cost effectively. Just as $1 of timely rehabilitation will save $5 of reconstruction, $1 of timely prevention will delay $5 of rehabilitation. Municipal roads and sidewalks best practices address two priorities: front-end planning and decision making to identify and manage pavement infrastructures as a component of the infrastructure system; and a preventive approach to slow the deterioration of existing roadways. The best practices set out will ensure for instance that the right treatment is selected for the right road at the right time and will provide guidance in implementing individual treatments successfully, e.g. crack-sealing, rut mitigation. Example topics include timely preventative maintenance of municipal roads; construction and rehabilitation of utility boxes; and progressive improvement of asphalt and concrete pavement repair practices.

Decision Making and Investment Planning

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

Environmental Protocols

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

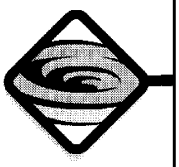


Potable Water

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

Transit

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



Storm and Wastewater

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

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ACKNOWLEDGEMENTS

The dedication of individuals who volunteered their time and expertise in the interest of the *National Guide to Sustainable Municipal Infrastructure* is acknowledged and much appreciated.

Stakeholders from Canadian municipalities and specialists from across Canada developed this best practice, based on information from a scan of municipal practices and an extensive literature review. The following members of the National Guide's Municipal Roads and Sidewalks Technical Committee provided guidance and direction in the development of this best practice. They were assisted by the Guide Directorate staff and by Applied Research Associates, Inc., ERES Consultants Division.

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Acknowledgements

This and other best practices could not have been developed without the leadership and guidance of the Project Steering Committee and the Technical Steering Committee of the *National Guide to Sustainable Municipal Infrastructure*, whose memberships are as follows:

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EXECUTIVE SUMMARY

The *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices* (InfraGuide) is intended to be a decision-making and investment planning tool as well as a compendium of technical best practices and innovations. InfraGuide will provide a road map to assist agencies in the cost-effective maintenance and rehabilitation of our municipal infrastructure.

This best practice should be of interest to managers and technical personnel responsible for the identification of pavement maintenance and rehabilitation needs and for the development of municipal pavement preservation budgets (maintenance and capital budgets). The practice describes a logical, systematic planning and budgeting process for pavement preservation. It provides a technically sound, business-oriented approach for taking care of the pavement infrastructure.

The priority planning and budgeting process builds on the best practices developed in Part A of the Guide dealing with decision-making and investment planning issues. The process starts with assembling a basic inventory of pavement infrastructure, section by section. Each pavement section should be periodically evaluated to determine its condition and the most cost-effective way to preserve it. The type of work required, the cost of the work, and the resulting extension of pavement life are described for the individual sections. A sum of these requirements represents the total annual pavement preservation needs.

It is important to prioritize the needs to ensure that the right pavement sections are treated at the right time. These priorities and their implications need to be presented to the decision makers in order for them to make informed choices. The first priorities are projects related to safety standards, followed by projects related to minimum pavement condition levels (based on approved levels of service), and by projects that will provide the best return on investments, such as sections requiring preventive maintenance. The projects that do not make it into the budget represent a backlog of pavement preservation needs.

The process presented in this best practice can provide objective information on pavement preservation needs to senior decision makers and the public. It can be used to quantify the link between the budget and the level of service provided to the public, and to support funding requests for pavement preservation.

The practice describes a logical, systematic planning and budgeting process for pavement preservation.

1. General

1.1 Introduction

Every municipality prepares a budget to preserve pavements, and every municipality has some sort of planning that precedes budgeting (Muntz, 1994). The quality of planning and the budgeting process have a major impact on the condition of the pavement network and on the life-cycle cost of maintaining it. The link between planning and budgeting is important. Planning should provide the basis for, and substantiation of, the budget. The budget should be based on well-documented pavement preservation needs.

The planning and budgeting procedures described in this best practice can easily be adapted to include other infrastructure assets, such as culverts and bridges, sidewalks, parks and recreational facilities, and buildings. It follows the principles, objectives, and methodology of pavement management and overall asset management. The description of the key principles and elements of municipal infrastructure asset management is provided in a consensus document prepared for the *National Guide to Sustainable Municipal Infrastructure.*[1]

The Pavement Design and Management Guide developed by the Transportation Association of Canada (TAC, 1997), as well as the *Pavement Management Guide* developed by the American Association of State Highway and Transportation Officials (AASHTO, 2001), provide useful information on pavement management processes including data requirements, data collection methods, pavement performance prediction, selection of maintenance and rehabilitation treatments, priority analysis, and other pavement management topics.

1.2 Purpose and Scope

This best practice provides a rational approach for the development of needs-based pavement preservation budgets. Considering the many activities involved in pavement management, this best practice concentrates on identification of needs, prioritization, and budgeting activities. These activities have a direct impact on the effectiveness of pavement preservation investments, and ensure that the right pavement sections are treated at the right time.

The description of the priority planning and budgeting process is illustrated using examples of practices obtained by interviewing representatives of 25 Canadian municipalities, known for using progressive pavement maintenance and rehabilitation techniques, and pavement management practices, on the topics of planning, budgeting, technical design, and implementation. The 25 municipalities were located in all regions of the country and included both small and large municipalities.

1.3 How to Use This Document

This document should be used together with other asset management tools and best practices dealing with the management of infrastructure needs. Some of these can be found on InfraGuide's Web site and several other best practices are referenced in Section 3 of this document.

The quality of planning and the budgeting process have a major impact on the condition of the pavement network and on the life-cycle cost of maintaining it.

1. *The Elements of an Asset Management System to Serve Municipal Infrastructure* for FCM/NRC in support of the National Guide, 2002.

1.4 Glossary

Asset management — A systematic process of maintaining, upgrading, and operating physical assets cost effectively, combining engineering principles with sound business practice and economic theory, and providing tools to facilitate a more organized, logical approach to decision making (TAC, 1999).

Budgeting — A process of developing, presenting, approving, and controlling a budget.

Multi-year planning — A process that plans for future preservation activities during a period that typically exceeds five years. In the context of pavement management, multi-year planning refers to planning, evaluating, and selecting pavement preservation treatments.

Network level — Activities carried out at the network level concern the entire network or a part of the network.

Pavement condition — A measure of the way the pavement serves the travelling public. Typically, pavement condition is evaluated in terms of pavement roughness and the severity and extent of surface defects, such as rutting, cracking, and the lack of skid resistance. Condition evaluation may also include structural evaluation and testing. Pavement condition can be described using the characteristics of individual defects such as rut depth, or using characteristics that combine the influence of several defects such as a pavement condition index.

Pavement maintenance treatments — All actions necessary for maintaining pavements in service, but excluding rehabilitation and reconstruction.

Pavement management — A process that assists decision makers in finding optimum strategies for providing, evaluating, and maintaining pavements in a serviceable condition.

Pavement management system — An application of pavement management principles that encompasses a wide spectrum of activities including planning and programming of investments, design, construction, maintenance, and periodic evaluation of performance.

Pavement performance — Pavement condition expressed over a period of time. In other words, pavement condition describes pavement characteristics at one particular time; pavement performance describes how the pavement condition changes over time.

Pavement preservation treatments — All types of pavement maintenance and rehabilitation treatments.

Planning — A process used to identify pavement preservation needs. It includes elements of inventory, condition evaluation, identification of needs, and prioritization.

Preventive maintenance treatment — A treatment performed to prevent premature deterioration of the pavement or to retard the progression of pavement defects. The objective is to slow down the rate of pavement deterioration and cost effectively increase the useful life of the pavement.

Programming — An activity that coordinates and schedules the implementation of infrastructure preservation actions and allocates funding for these actions.

Project level — Activities at the project level concern a specific pavement section.

Rehabilitation treatments — Actions taken to restore the initial pavement condition, such as pavement overlay or in-place recycling. Pavements may receive several rehabilitation treatments (undergo several rehabilitation cycles) before they are reconstructed.

Roadway class — Classification of roadways into functional categories, such as expressways, arterials, collectors, and residential streets.

2. Rationale

2.1 Background

Decision making for pavement maintenance and rehabilitation should be integrated into a yearly management cycle of planning, budgeting, engineering, and implementation activities. There are eight basic steps in the yearly management cycle: review or establishment of levels of service, pavement inventory, identification of needs, prioritization, budgeting, project design, project implementation, and performance monitoring. These eight basic steps are shown in Figure 2–1 and are briefly described in this section. A detailed description of the eight steps is given in Section 3.

Figure 2–1: Decision-making framework for pavement preservation

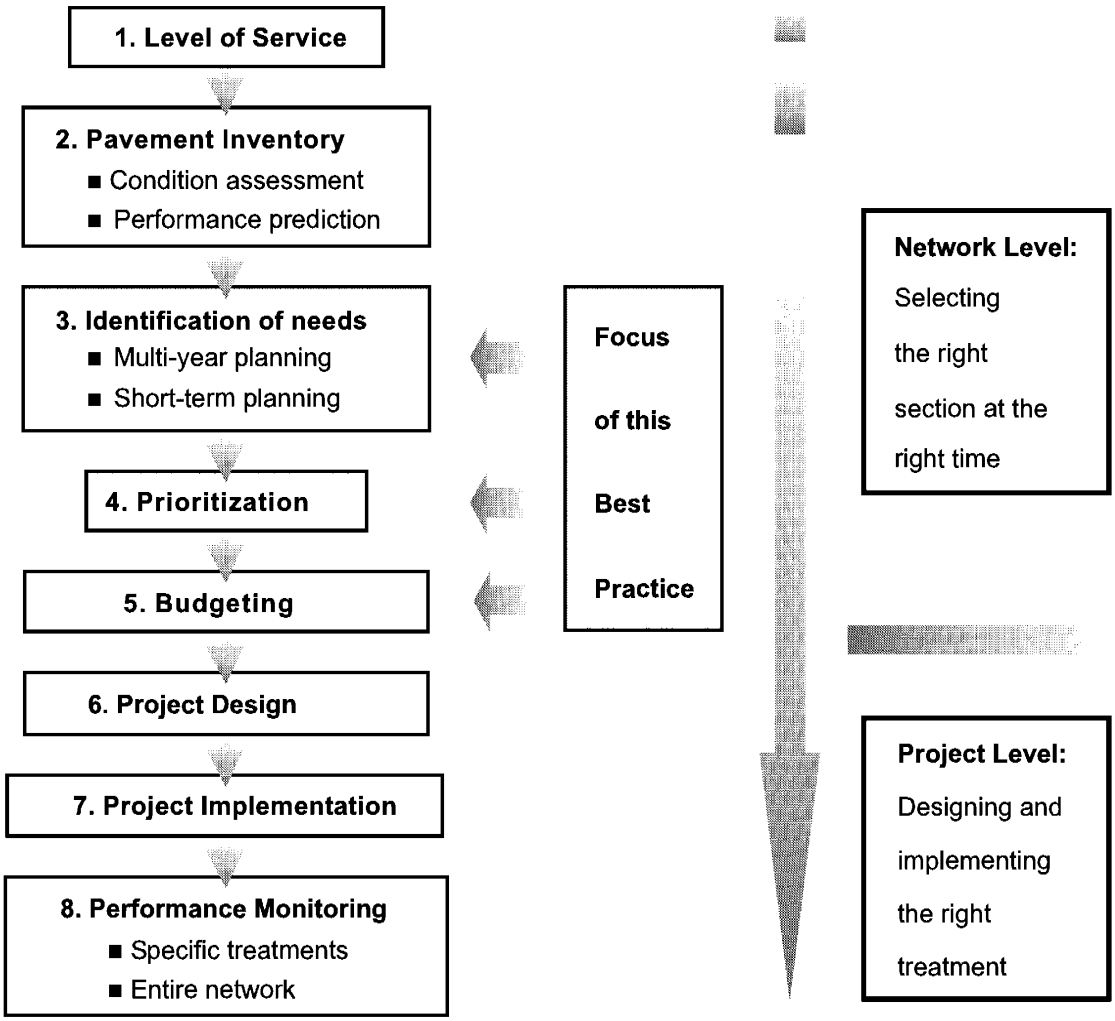


Figure 2–1
Decision-making framework for pavement preservation

Step 1 involves reviewing or establishing the levels of service regarding pavement condition. This activity takes into account a number of factors (such as strategic directions, the condition of the pavement network, and financial resources). The levels of service should be endorsed by a municipal council.

Step 2 is to establish a pavement inventory. Every municipality needs to know which assets it owns and their condition to manage the assets effectively.

Step 3 is the identification of needs. Each pavement section is reviewed to determine the appropriate pavement preservation treatments to be carried out in the future. The process yields a list of candidate pavement preservation projects.

The prioritization in Step 4 is one of the most important elements in the management cycle. It determines which of the candidate projects will become recommended priorities.

Step 5, budgeting, secures the budget and controls spending. Also, as part of the budgeting process, projects are programmed and packaged to minimize inconvenience to the travelling public and to improve construction efficiency.

The first five steps of the management cycle represent network-level management activities as shown on the right side of Figure 2–1. The objective of these activities is to ensure the right pavement sections receive treatment at the right time. The rest of the steps (6 to 8) can be viewed as project-level activities that ensure the right sections receive the right treatment.

The project design in Step 6 provides technical direction for the most cost-effective treatment, including type of materials, layer thickness, and construction procedures. Step 7, project implementation or the construction stage, must be supported by quality control and quality assurance procedures. Step 8, performance monitoring, is at the end of the management cycle and provides feedback on how the process is working.

2.2 Benefits

This best practice should be of interest to management and technical personnel responsible for the identification of pavement preservation needs and the development of budgets. Benefits of this practice can be realized in several ways.

- It provides procedures on how to determine, document, and justify funding needs for pavement preservation.
- It provides directions on how to prepare prioritized, needs-based budgets, and how pavement preservation needs can be translated into funded projects using a logical, systematic, planning and budgeting process.
- It promotes the use of best practices and provides a benchmark for pavement preservation decision making for both small and large municipalities.
- It can provide objective information on pavement preservation needs, and on long-term implications of budget decisions, to senior decision makers and the public. It can be used to support funding requests for pavement preservation by showing the relationship between the budget and the level of service provided to the public.
- It promotes the cost-effective use of pavement investments to return maximum benefits to the community.

3. Methodology

The description of the methodology follows the eight steps shown in Figure 2–1. The focus is on the identification of needs, prioritization, and budgeting as shown in Figure 2–1.

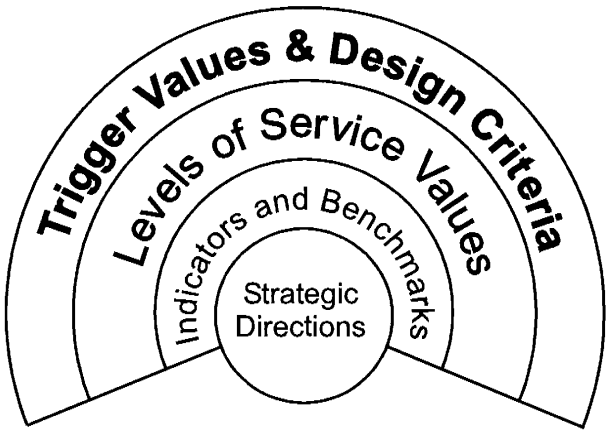
3.1 Levels of Service (Step 1)

At the start of the priority planning process, it is important to consider the objectives. What level of service is the road department expected or mandated to provide? Many municipalities, such as the City of Winnipeg, strive to preserve pavements at the current condition or current level of service. Winnipeg has also carried out an innovative study to obtain input from local residents on required pavement condition. The study involved residents riding in city-driven passenger cars and evaluating the condition of the pavement for typical city streets.

The development of service levels starts with strategic infrastructure planning. The purpose of strategic planning is to coordinate various infrastructure needs and major infrastructure investments to achieve the social and economic goals of the municipality. The resulting strategic directions and plans should drive all major infrastructure initiatives, including pavement preservation. Strategic planning is the subject of the best practice *Planning and Defining Municipal Infrastructure Needs.*

Figure 3–1 illustrates how strategic directions radiate and influence the selection of indicators and benchmarks, levels of service values and, ultimately, the selection of trigger values and design criteria.

Figure 3–1: Types of indicators, levels of service, and trigger values



Types of Indicators, Levels of Service, and Trigger Values

For Decision Levels
- Strategic
- Tactical
- Operational

For Asset Classes
- Roadways
- Pavements
- Sewers
- Etc.

For Priority Levels
- Legal and safety requirements
- Minimum level of service
- Cost-effectiveness level
- Target (desirable) level

Figure 3–1
Types of indicators, levels of service, and trigger values

At the start of the priority planning process, it is important to consider the objectives. What level of service is the road department expected or mandated to provide?

Figure 3–2
Types of service levels and trigger levels

Indicators and benchmarks are used to translate strategic directions into measures required for infrastructure planning and decision making. A framework for the development of performance measures and indicators is outlined in the best practice *Developing Indicators and Benchmarks.*

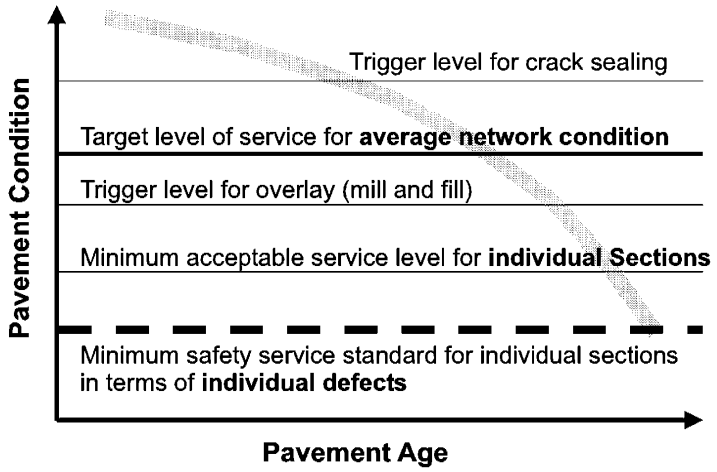
In addition to the **types** of indicators and benchmarks, it is also necessary to establish the **level** of performance indicators and measures, or levels of service. The methodology for establishing the levels of performance indicators is described in the best practice *Developing Levels of Service.* A city or municipal council should review and approve the policies on levels of service used by a road department.

The final step in the process of translating and quantifying strategic directions is the establishment of trigger values and design criteria that support levels of service. Trigger values are used, usually on an operational level,[2] to decide when a pavement preservation action should be carried out whereas design criteria are used to set specific infrastructure design parameters (e.g., pavement width).

Performance measures, levels of service, and trigger values can be formulated for different decision levels, asset classes, and priority levels as shown at the bottom of Figure 3–1. The levels of service established for different priority levels will be used in Section 3.3.1 to determine prioritized needs.

Figure 3–2 shows, as an example, characteristic types of levels of service and trigger values used in pavement management. These characteristic types of levels of service and trigger values are also described below.

Figure 3–2: Types of service levels and trigger levels



2. The definitions of operational, tactical, and strategic decision levels are provided in the best practice *Developing Indicators and Benchmarks* (page 5).

Minimum safety-related levels of service are typically defined in terms of individual pavement defects, such as potholes, cracking, and wheel track rutting. For example, a standard may state that potholes on an arterial roadway should not be larger than 600 cm^2 in area and 8 cm deep. If such potholes appear, they should be filled within a specified time period (Anderson, 2002). A section with a history of developing such potholes should be scheduled for rehabilitation to meet minimum safety levels of service. Minimum or mandatory levels of service are also called *service standards.*

The minimum acceptable level of service is the minimum condition for individual pavement sections. The sections at or below this level should be improved at the first opportunity. Usually, different minimum acceptable levels of service are assigned to different roadway classes.

Trigger values are usually associated with specific pavement preservation treatments (such as sealing cracks in asphalt concrete pavement or sealing joints in concrete pavement) and are related to the need to apply a preservation treatment at the right time to be effective, or before the pavement reaches a condition where a different, more expensive treatment would be required. There are also general trigger values. For example, City of Regina guidelines recommend the range of PCI[3] to be 50 to 70 for overlays, 30 to 50 for partial reconstruction, and <30 for total reconstruction. The City of Edmonton has also established trigger levels for identifying rehabilitation candidates before the repairs become too expensive.

Target levels of service represent a desirable level of service for the entire pavement network or a portion of the network. For example, the average condition of arterial roadways may be set to be at least 70 on a scale from 0 to 100 while, at the same time, the maximum percentage of arterial roadways in "poor" condition (e.g., below 40) should typically be less than 10 percent.

3.2 Pavement Inventory (Step 2)

Pavement inventory is the key building block for pavement decision making. The inventory must include the size and type of pavement assets as well as their condition. A conceptual outline of data collection and information management for municipal infrastructure is provided by the best practice *Developing Indicators and Benchmarks.* The best practice *Best Practices for Utility-Based Data* describes the process of identifying, storing, and managing utility-based information and data.

3.2.1 Inventory Data

The challenge is to decide what to include in the pavement inventory and how the data should be stored and displayed. Also, a pavement inventory should be organized as part of a roadway inventory, or even better, as part of a municipal asset inventory.

Current trends in the storage and display of inventory data include automated mapping, the use of geographical information systems,[4] and of video data. Lee and Deighton (1995) developed a mapping system for Cornwall, Ontario that can display various infrastructure data, such as pavement or water main data, on a common map. The U.S. Department of Transportation (2001) developed the *Data Integration Primer* that explains principles and options for developing integrated databases.

Current trends in the storage and display of inventory data include automated mapping, the use of geographical information systems, and of video data.

3. Pavement Condition Index on a scale from 0 to 100 where 100 represents a new pavement.

4. All computerized applications, which analyze and display location data or perform mapping functions are typically referred to as GIS applications.

The first step in developing an inventory is to divide the network into a number of uniform sections or links. For example, a section should have a uniform pavement structure, performance, and traffic volumes. The sections may be one city block long or several kilometres long. As a minimum, the pavement inventory should include the following:

- the location, roadway class, length, width, and area of the pavement section;
- the date of the original construction and the dates of subsequent rehabilitation treatments;
- a description of the original pavement structure and the subsequent pavement preservation treatments;
- pavement condition (past and current); and
- traffic data (e.g., estimated annual average daily traffic and the percentage of commercial vehicles).

To identify maintenance and rehabilitation needs, particularly preventive maintenance needs, the condition evaluation must be timely, (usually annual or biennial) and detailed.

3.2.2 Condition Evaluation

Pavement condition evaluation serves two purposes: to identify maintenance and rehabilitation needs, and to monitor the health of the pavement network.

To identify maintenance and rehabilitation needs, particularly preventive maintenance needs, the condition evaluation must be timely, (usually annual or biennial) and detailed. The requirements for the condition evaluation for preventive maintenance purposes are presented in the best practice *Timely Preventive Maintenance for Municipal Roads.* Briefly, condition evaluation requires the identification of individual pavement defects, such as transverse cracks, and the evaluation of their severity and extent. If the condition evaluation meets the preventive maintenance requirements, it will also meet the rehabilitation requirements.

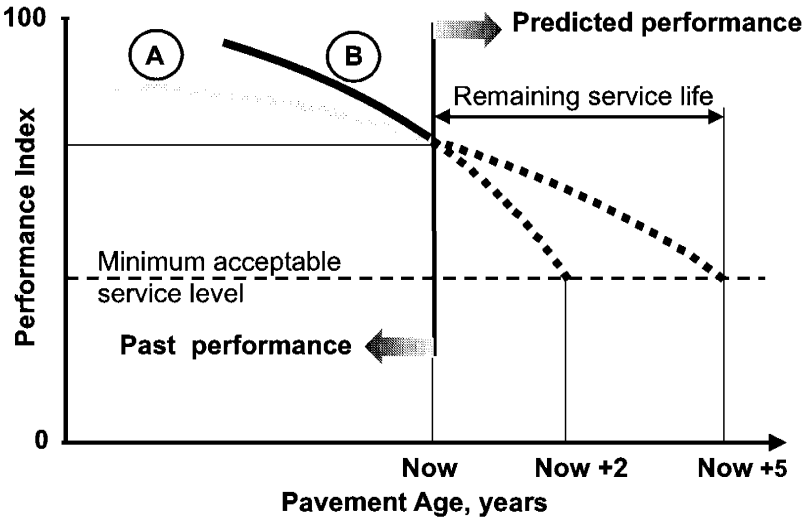
Monitoring the health of the pavement network must be objective and repeatable to produce true trends. It typically involves assessment of roughness and pavement distresses. Some agencies classify pavements into three or five categories (from very good to very poor); others use composite performance indicators. For example, Edmonton uses a pavement quality index that combines the influence of roughness, distresses, and structural adequacy. Monitoring of the network condition should be done about every second year for high traffic volume facilities and about every third year for local roads and streets.

3.2.3 Pavement Performance Prediction

Because it can take several years to advance a project from planning to implementation, the selection of preservation treatments must consider the pavement condition at a future time and not just at the time the selection is made. Thus, some degree of pavement performance prediction is always built into the treatment selection process.

Figure 3–3 shows the importance of pavement performance prediction. The present condition rating of the two pavements in Figure 3–3 is the same. However, pavement B has a higher rate of deterioration than pavement A. Thus, pavement B will reach the minimum acceptable service level sooner, and will require a pavement preservation treatment earlier. The predicted rate of pavement deterioration can also be used as one of the factors to prioritize and select candidate sections for treatment. Figure 3–3 also defines the remaining service life. When known for all sections in the network, the remaining service life can be used to characterize the overall condition of the pavement network.

Figure 3–3: Need for pavement performance prediction



Performance prediction is a critical requirement for the identification of future pavement preservation needs. Pavement performance depends on many local factors and is not easily transferable from municipality to municipality. Long-term predictions (for five or more years) involve how long the existing pavements will last before they require a treatment (as shown in Figure 3–3), as well as how the individual sections will be rehabilitated during the intervening years, and how these rehabilitation treatments will perform. This is a very challenging task. Additional details on pavement performance prediction are given in Appendix A.

3.3 Identification of Needs and Prioritization (Steps 3 and 4)

The identification and prioritization of needs for larger municipalities cannot effectively be accomplished without the aid of specialized computer software. There are many pavement management software products on the market that can be purchased and customized by municipalities. Municipalities also frequently retain consultants to assist in customizing or operating the software.

There are two types of identification of needs:

- the multi-year identification of needs for time horizons of about five years or more; and
- the short-term identification of needs for shorter periods.

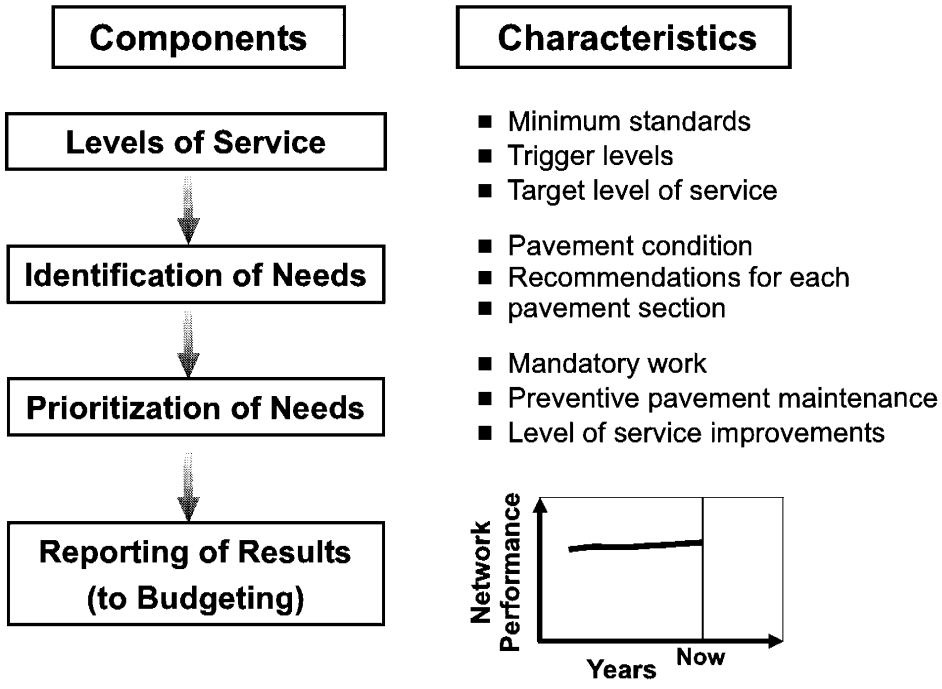
The identification and prioritization of needs for larger municipalities cannot effectively be accomplished without the aid of specialized computer software.

Figure 3–4
Short term planning and prioritization

3.3.1 Short-Term Identification of Needs and Prioritization

Because of the complexity of multi-year planning procedures, it may be easier for municipalities just starting to implement pavement management systems to use short-term planning and prioritization procedures. Figure 3–4 shows the connection between the levels of service, identification of needs, prioritization, and budgeting for short-term planning and prioritization.

Figure 3–4: Short-term planning and prioritization



Short-Term Identification of Needs

The following step-by-step description of identification of needs is simplified for brevity and represents a typical process. The process combines all pavement preservation needs together (maintenance as well as rehabilitation treatments).[5]

1. The pavement inventory, including pavement condition, is updated.
2. A decision must be made as to what types of treatment should be included in the needs. In general, all roadway maintenance and rehabilitation activities that can be planned at least a year in advance should be included. Such activities may include, for example, ditching, repair or replacement of culverts, sealing cracks and joints, machine patching, asphalt concrete overlays, and full-depth repairs of Portland cement concrete pavements.
3. Each roadway section in the inventory is reviewed to determine if the section requires a pavement preservation treatment in the next few years. Many sections may not require any treatment, some sections may require a preventive maintenance treatment (e.g., crack or joint sealing), and some may require other types of maintenance or rehabilitation. The candidate treatments can be identified using engineering judgment, agency-specific guidelines and decision trees, and general guidelines.
4. The best treatment for the given section is selected. Typically, the selected treatments are generic (e.g., one-lift overlay or a multi-lift overlay), particularly if the treatments are selected by software. The selection of the treatments must be realistic and must consider the appropriate levels of service as outlined in Section 3.1. It is important to realize that the identification of needs is not a creation of a wish list, but a documentation of the needs that are necessary on the basis of approved and mandated standards and levels of service.
5. Each section, and its recommended treatment, are described in terms of location (and road class), treatment type, recommended construction year, estimated cost and, very importantly, priority level. The priority level shows the main reason why the treatment is recommended for implementation. One of the following priority levels, as shown in Figure 3–1, should be assigned to each recommended pavement preservation treatment:
   A) minimum safety-related levels of service need to be met;
   B) minimum acceptable levels of service need to be met;
   C) there are preventive maintenance and cost effectiveness concerns (includes projects where timing is very important to achieve cost effectiveness); or
   D) projects are initiated to achieve a target level of service.
6. The individual treatments are sorted by the priority levels (A to D) and by roadway classes. The resulting list represents the total documented needs for the preservation of the road system.

Prioritization of Short-Term Needs

If it is expected that some projects may not be funded because of limited funding, the list needs to be prioritized. Projects that address minimum safety-related levels of service are typically considered mandatory and are not prioritized. The same applies to carry-over projects that need to be completed and already approved projects.

In general, all roadway maintenance and rehabilitation activities that can be planned at least a year in advance should be included.

5. Some municipalities prepare separate budgets for maintenance (operating) and rehabilitation (capital) work. While this may be necessary for administrative reasons, for cost efficiency and technical reasons, it is preferable to have only one integrated process for the identification and prioritization of pavement preservation needs.

There are many ways to prioritize projects. The priority levels, together with roadway classes already convey basic priorities. Thus, projects that belong to priority level B (minimum acceptable level of service) and apply to expressways may have higher priority than projects that belong to priority level D (target levels of service) and apply to residential streets. It is easier and preferable to prioritize projects that belong to the same priority level and roadway class than to prioritize projects across priority levels and roadway classes. Typical prioritization criteria include the following considerations that can be applied individually or in combination:

- pavement condition (in relation to the level of service);
- roadway class;
- traffic volume and percentage of commercial vehicles; and
- cost effectiveness (benefit-cost ratio).

To be credible, the process of identification of needs and prioritization must be consistent, transparent, and logical.

To be credible, the process of identification of needs and prioritization must be consistent, transparent, and logical. The cities of Corner Brook, Gander, and Saint John's, Newfoundland and Labrador use a common outside agency to provide them with recommended five-year pavement preservation plans. In the early 1990s, the Ontario Good Roads Association developed a short-term priority planning and budgeting method for road maintenance and distributed it to all Ontario municipalities (Muntz, 1994).

Reporting Results

Short-term planning does not enable the projection of future network condition. However, it is possible to obtain historical network performance trends (as shown in the bottom portion of Figure 3–4). Also, the backlog of projects, and the annual change in the backlog, can provide an indication of whether the road system is deteriorating or improving.

3.3.2 Multi-Year Identification of Needs and Prioritization

By answering the following questions, multi-year identification of needs and prioritization leads to many new possibilities.

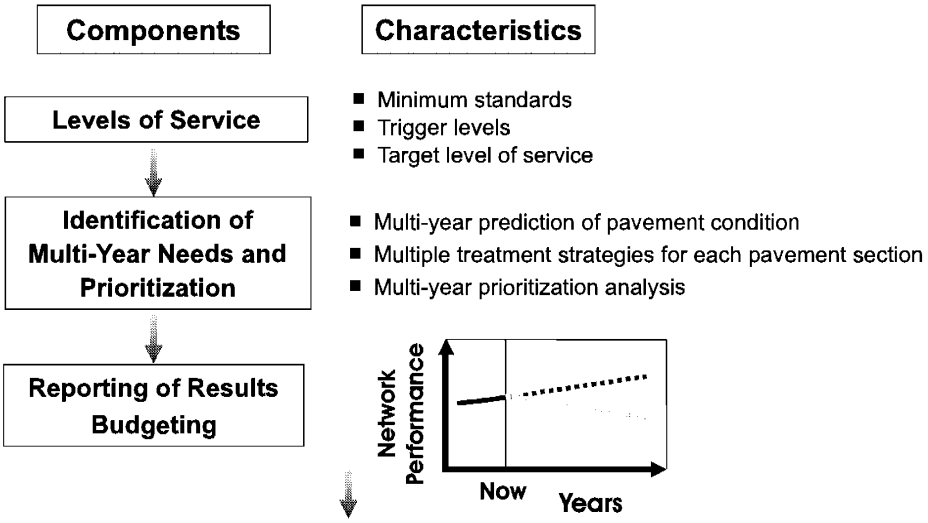
- What funding is required in future years to achieve target levels of service?
- What will be the future condition of the network given projected funding levels?
- How much additional funding will be required in the future to compensate for a budget cut now?
- How will the condition of the pavement network change if funds are diverted to preventive maintenance?

Multi-year planning also improves engineering and economic decision making, because it enables the agency to evaluate the long-term impacts of accelerating or postponing projects from one year to another, to evaluate the trade-offs between lower-cost treatments that have to be paid for now versus costlier treatment that will need to be paid for later, or the impact of diverting funds to preventive maintenance. The basic components and characteristics of multi-year planning are shown in Figure 3–5 and are outlined in the following sections.

Figure 3–5
Multi-year planning and prioritization

Figure 3–6
Alternative treatments and alternative timing of treatments

Figure 3–5: Multi-year planning and prioritization



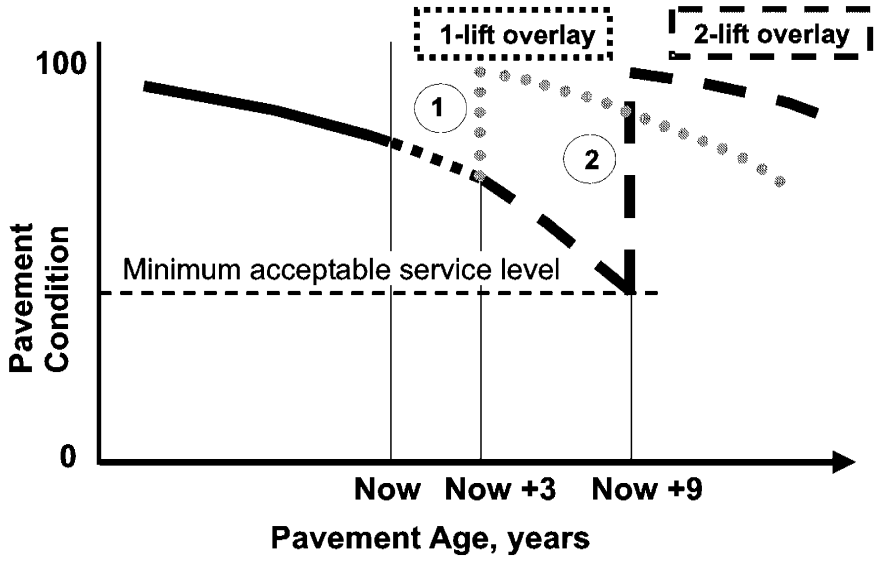
Generation of Feasible Alternatives

The success of multi-year planning and the accuracy of future funding requirements depend on multi-year predictions of pavement performance (see Appendix A).

The prioritization analysis can consider several treatment options in each analysis year (FHWA, 1997). The concept is illustrated in Figure 3–6 for one pavement section.

For illustrative purposes, of the many options that can be generated for different years, only two alternatives are assumed to exist. The first is a single lift resurfacing three years from now; the second is a two-lift resurfacing nine years from now. With multi-year prioritization analysis, these two alternatives (pay now or pay later) can be evaluated on an equal footing, while still considering other projects.

Figure 3–6: Alternative treatments and alternative timing of treatments



Multi-Year Prioritization

An important feature of multi-year prioritization analysis is its ability to prioritize (or optimize) competing treatments using the cost effectiveness of individual treatments. To do this, each treatment is characterized by its cost and benefit. The cost aspect of the treatment should be based on its life-cycle cost as much as possible (Zimmerman et al., 2000). However, in practice, agencies use only initial treatment costs and perhaps routine maintenance costs, because the exact nature of the treatments is not known in the planning stage (at the network level).

Benefits, or effectiveness of the treatment, are based on the additional pavement life the treatment is expected to provide, and may include the reduction in user costs.

Benefits, or effectiveness of the treatment, are based on the additional pavement life the treatment is expected to provide, and may include the reduction in user costs. For example, if two projects provide the same benefit in terms of additional pavement life, the project on the roadway serving a higher traffic volume may be chosen first. This type of analysis, driven predominantly by annual average daily traffic volumes and pavement surface condition, is used by the City of Brampton, Ontario.

Dividing the effectiveness of a treatment by the costs of the treatment results in a cost-effectiveness ratio, which is used to prioritize candidate projects. The selection of projects is typically done using an incremental benefit-cost analysis. Multi-year prioritization analysis yields multi-year prioritized lists of pavement preservation projects for different years.

Integrating Preventive Maintenance with Multi-Year Prioritization

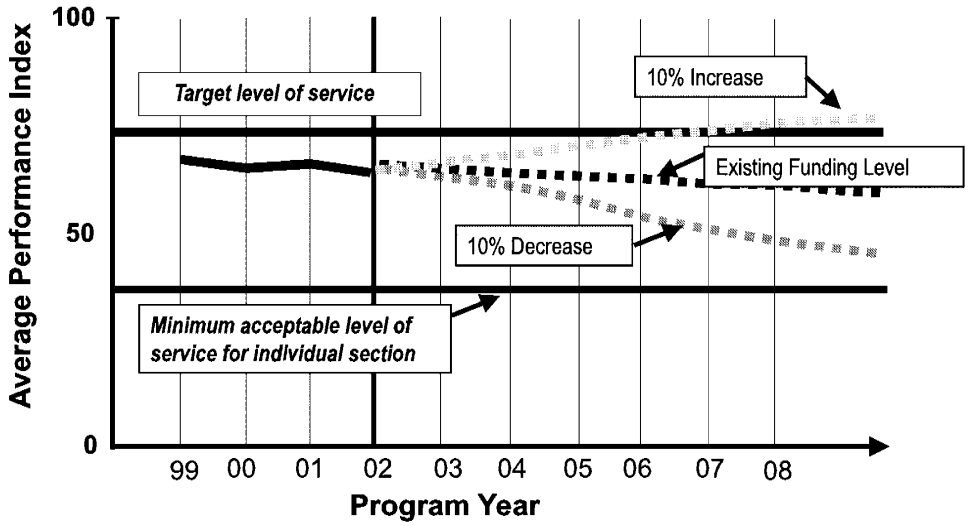
The candidate projects included in multi-year analysis should also include preventive and other maintenance activities. The cost effectiveness of these activities can be compared with the cost effectiveness of activities recommended for other priority levels. Consequently, the distinction between funding for preventive maintenance and funding for target levels of service can be made directly through cost-effectiveness analysis.

Reporting Results and Consequences of Different Funding Levels

Depending on funding, the projects not funded one year are considered for funding in the subsequent year (or years). By changing the amount of funding, the amount of work will change, and so will the condition of the pavement network. However, regardless of the funding, the list of prioritized projects still represents the best value for the money.

The results of multi-year prioritization can show the relationship between the pavement investment and the resulting level of service provided to the community. An example of this type of analysis is illustrated in Figure 3–7, which shows the consequences of changes in proposed funding levels. A 10 percent growth in funding, sustained for several years, will result in achieving the desirable target level of service in 2007.

Figure 3–7: Consequences of different funding levels



The average municipality-wide condition of the network may not be the best indicator of the network condition, because it can hide the existence of substandard sections. Figure 3–8 shows projected trends in the distribution of the network between various pavement condition categories, assuming a 10 percent increase in funding. This type of reporting overcomes the limitation of using the average condition only.

Figure 3–8: Estimated performance of a pavement network

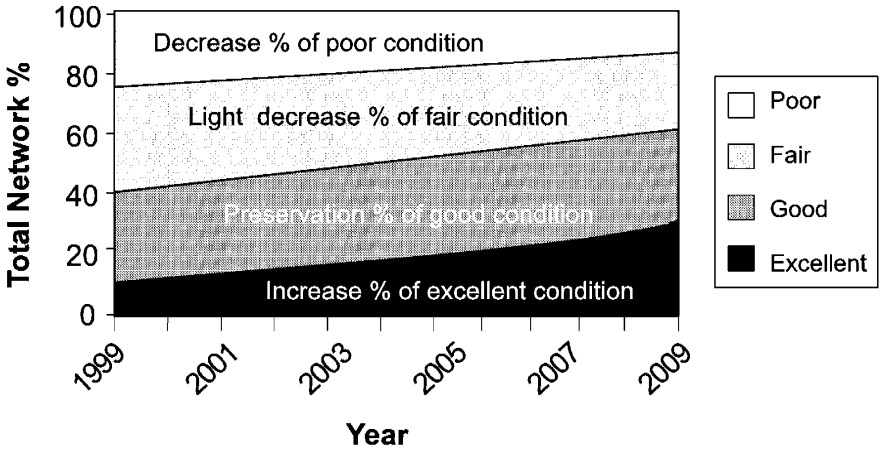


Figure 3–7
Consequences of different funding levels

Figure 3–8
Estimated performance of a pavement network

The average municipality-wide condition of the network may not be the best indicator of the network condition, because it can hide the existence of substandard sections.

Figure 3–9
Budgeting as a combination of technical and financial decision meaking

Multi-year prioritization analysis is a powerful and useful decision support tool for managing pavement infrastructure.

Simplified Multi-Year Prioritization Analysis

Multi-year prioritization software typically supports different levels of detail. A municipality can start with a simplified system and improve it with experience and as more data become available. The simplification can be accomplished through:

- limiting the length of the planning period;
- simplifying the pavement prediction procedures;
- restricting the number of candidate treatments per section; and
- using simple prioritization indicators, such as pavement condition and traffic volumes, rather than a cost-effectiveness ratio.

Prioritized pavement preservation needs provide important input for the preparation of annual and multi-year budgets. However, budgets must also consider many other funding needs and programming considerations.

Municipal Applications

Multi-year prioritization analysis is a powerful and useful decision support tool for managing pavement infrastructure. It requires a long-term commitment to succeed and must be supported by a computerized pavement management system. Multi-year prioritization analysis is usually confined to large municipalities that face complex funding choices. Examples of municipalities that practice multi-year planning and prioritization include the cities of Edmonton, Saanich, Toronto, and Winnipeg.

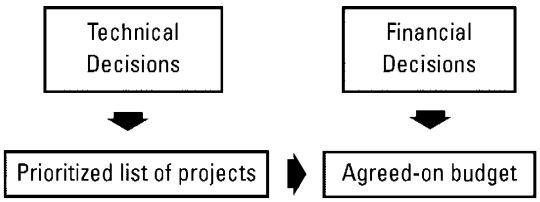
3.4 Budgeting (Step 5)

The selection of projects to be included in the budget should be based on the efficient allocation of resources to different programs (e.g., infrastructure preservation, expansion of capacity, environmental protection, and increased safety) and to different assets (e.g., pavements, bridges, sewers). The efficient allocation of resources, and the ability to evaluate the consequences of different budget allocations, is a principal premise of asset management.

3.4.1 Prioritized Budgeting

All municipalities carry out annual budgeting for the preservation of transportation infrastructure. Budgeting builds on the results of planning and prioritization activities, and produces a budget — a financial document that determines how the money will be invested in the infrastructure. Budgeting combines technical and financial decision making as illustrated in Figure 3–9.

Figure 3–9: Budgeting as a combination of technical and financial decision making



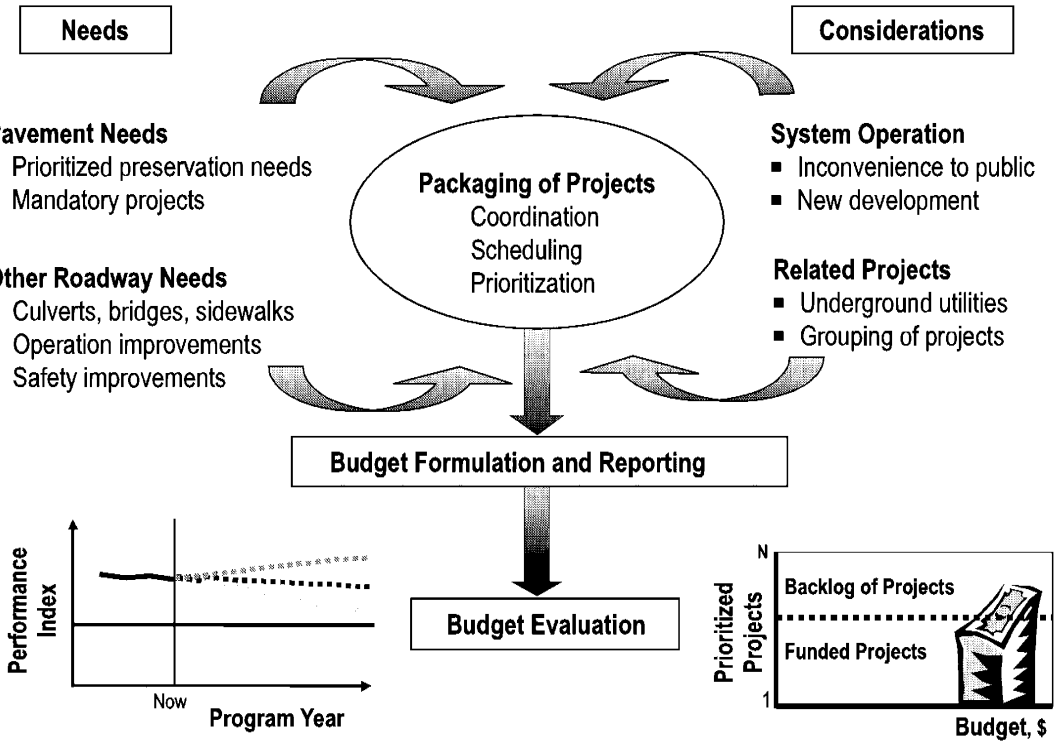
A municipal budget consists of many line items. Some municipalities have a separate budget entry for maintenance and for capital projects. This may serve a useful administrative purpose. However, it is desirable that both budget entries are based on prioritized needs where maintenance and rehabilitation activities are in synergy.

While historical budget allocations assist in providing an overall indication of available resources, the main input to the budgeting process should be the list of documented and prioritized needs and not last year's budget.

3.4.2 Programming and Budgeting

Main budgeting activities are schematically illustrated in Figure 3–10. Programming and packaging of projects must take into account a number of needs and considerations.

Figure 3–10: Key budgeting activities



The needs include the following.

- *Prioritized pavement preservation needs.*
- *Other roadway needs* include other roadway components (e.g., culverts, bridges, and sidewalks), operational improvements (e.g., widening at an intersection and system expansion), and safety improvements.

The considerations include the following.

- *System operation* includes staging projects to minimize inconvenience to the travelling public and advancing projects because of new residential and industrial development.
- *Related projects,* such as work on underground utilities, should be coordinated to minimize disruption to the public. This is the subject of a separate best practice *Coordinating Infrastructure Works.* Grouping similar projects within one or more municipalities can provide economies of scale.

The results of the budget allocation can be quantified and reported using the following means.

- Show the consequences of different budgets in terms of pavement condition as illustrated in figures 3–7 and 3–8.
- List the specific projects that will not be done, because of funding limitations.
- Track the quantity of unfunded needs, and the changes in unfunded needs, from year to year.
- Monitor network performance trends. For example, the City of Calgary monitors long-term trends in terms of network size, network condition, and annual spending per square metre of pavement.

Regular condition evaluation of all the pavement sections in the network can provide a clear indication of the long-term trend in the health of the network.

3.5 Project Design (Step 6)

The priority planning and budgeting process determines which sections should receive pavement preservation treatments and during which year, the approximate type of the treatment (e.g., a thin overlay), and the estimated cost of the treatment. Project design determines the actual treatment type and provides additional details required for the construction of the project (such as the layer thickness, type of material, and construction methods). It often uses the results of physical tests of the existing pavement materials.

Over the years, many agencies have developed various technical design aids, such as pavement design and rehabilitation procedures, manuals, specifications, and guidelines. Best practices in this area, developed by the National Guide include *Timely Preventive Maintenance for Municipal Roads, Rut Mitigation Techniques at Intersections, Guidelines for Sealing and Filling Cracks in Asphalt Concrete Pavements*, and other practices in preparation. We invite the reader to visit the InfraGuide Web site at *www.infraguide.ca* for a list of best practices.

The systematic way to approach the design of pavement maintenance and rehabilitation treatments is through life cycle cost analysis (LCCA). LCCA takes into account the cost of the initial constructions as well as all subsequent maintenance and rehabilitation treatments and, if relevant, user costs. An example application of LCCA is provided in the best practice *Timely Preventive Maintenance for Municipal Roads.*

3.6 Project Implementation (Step 7)

The two main decision-making concerns during the implementation stage are the selection of construction agents (in-house, contractors) to carry out the work and inspection procedures during construction.

In addition to quality control and quality assurance procedures, many municipalities use construction warranties. Warranties provide a catch-all provision to ensure basic construction quality. Warranties are important for pavement preservation treatments where the construction procedures and the selection of materials are difficult to specify and enforce (e.g., for sealing cracks in asphalt concrete pavements and for micro-surfacing). Several municipalities use one to three year warranties for "thin" paving jobs and up to five year warranties for rehabilitation and reconstruction work.

3.7 Performance Monitoring (Step 8)

Periodic pavement performance monitoring is important for both individual projects and for the entire pavement network. The cities of Edmonton and Toronto periodically evaluate past pavement preservation treatments, particularly treatments that are new. This enables them to expand, change, or discontinue the use of a particular treatment based on the cost effectiveness of the treatment. Regular condition evaluation of all the pavement sections in the network can provide a clear indication of the long-term trend in the health of the network.

Performance monitoring is also discussed in Section 3.2.2.

4. Implementation

This best practice describes how a municipal road department can develop pavement preservation budgets through a logical process of identifying and prioritizing needs for each section of road in the system. The main implementation steps and challenges include the following.

System benefits — Management and technical leadership must be convinced that the process will provide benefits to the residents, and to the agency.

Support by council — Acceptance and support by municipal council is vital.

Management commitment — The implementation of the process takes time and may be labour intensive. The process may change the way the pavement preservation business was done and may affect agency staff. Long-term commitment and support by management is required for successful implementation and operation of the process.

Establishing technical aspects — The process must be technically sound and reflect local conditions (e.g., environment, material availability, and contracting industry). Because the process is typically a computer-assisted decision support system, it will require ongoing software support.

Long-term commitment — The benefits of the process increase with time and with experience. For example, it takes several years of data collection to obtain pavement performance trends and calibrate pavement performance models. The availability of good inventory data is necessary to make the process work. The continued desire to succeed on the part of all principal participants is required.

Ongoing support — Identifying and prioritizing needs incurs costs and requires trained personnel.

5. Expected Outcome

The priority planning and budgeting process is a valuable decision-support tool. It can provide the road department and the municipality with many benefits and management improvements, including:

- an up-to-date inventory of the road network and its condition;
- a summary listing, for each section of the network, of current and future pavement maintenance and rehabilitation needs;
- a prioritized listing of pavement maintenance and preservation needs using sound technical analysis (separate listings can be produced for different roadway classes, such as arterials and collectors, and for different priority levels, for example minimum acceptable condition level, preventive maintenance/cost effectiveness, and improvement of service levels);
- a prioritized listing of needs, section-by-section, for budgeting considerations (a budget plan);
- the ability to evaluate the consequences of different funding levels on the condition of the pavement network and on the way the service levels are met (to help decision makers evaluate the short- and long-term impacts of their decisions);
- trends in the condition of the pavement network;
- a summary of unmet needs (infrastructure deficit) in terms of specific projects; and
- the optimal use of available funding by performing the right pavement preservation activities at the right time and on the right sections.

Appendix A:
Pavement Performance Prediction for Multi-Year Planning

This appendix contains a brief outline of the pavement performance prediction required for multi-year planning and prioritization analysis. The reliable prediction of pavement performance is the key requirement for estimating future funding needs. Reliable prediction is also important in selecting pavement preservation treatments, because the treatments are selected on the basis of their costs and predicted performance (benefits).

Performance prediction for multi-year identification of needs and prioritization consists of four prediction tasks as shown in Figure A–1. These prediction tasks must be systematically completed for all pavement sections in the network:

1. performance prediction of the existing pavement sections;
2. prediction of the treatment type;
3. prediction of the pavement condition immediately after a treatment is applied; and
4. performance prediction of the new treatment.

Figure A–1: Pavement performance prediction for multi-year prioritization

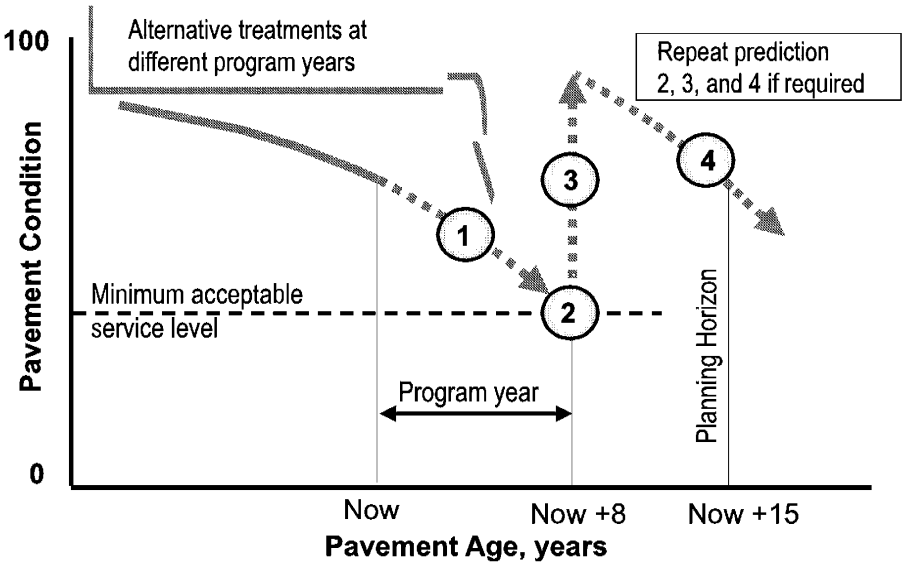


Figure A–1
Pavement performance prediction for multi-year prioritization

Figure A–2
Multiple alternatives evaluated during multi-year analysis and prioritization

A.1 Performance Prediction of the Existing Pavement

If the existing pavement is new, or if the condition of the existing pavement was not evaluated before, a reasonable approach is to assume its future performance will be similar to the performance of similar sections. For example, if the average life of new arterial pavements before resurfacing is 16 years, it is assumed that all new arterial pavements will last 16 years. The average performance of arterial pavements (and pavements for other roadway classes) must be established by developing typical performance curves for different pavement types (flexible, exposed concrete, and composite).

If the condition of the pavement was evaluated on at least one previous occasion, the typical approach is to extrapolate the existing trend to the future. The extrapolation follows the typical curve.

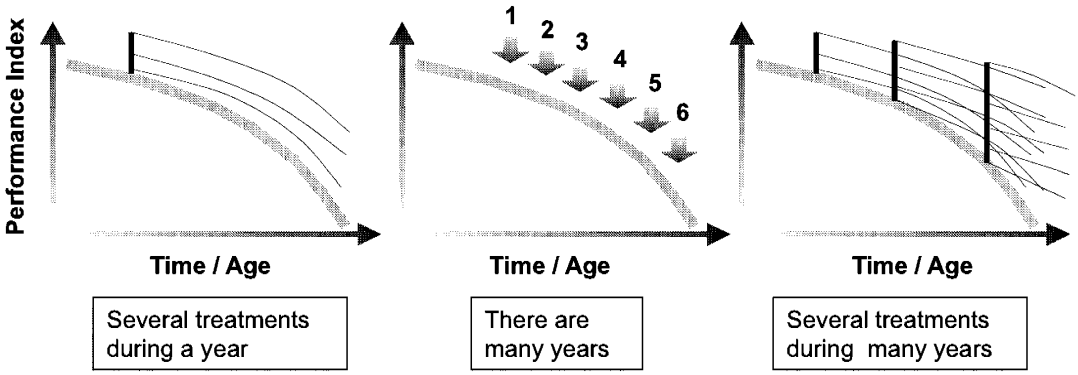
An alternative approach is to express typical performance curves in terms of probabilities. This leads to Markov probability models.

A.2 Prediction of the Treatment Type

Two important points must be made. First, a preservation treatment may include all types of pavement preservation treatments planned a year or more in advance, such as sealing cracks and joints, machine patching, overlays, partial and full depth repairs of Portland cement concrete pavements, etc. Second, different treatments may be implemented during different program years. This results in a considerable number of possible combinations of program years and treatments as illustrated in Figure A–2. During the prioritization, software considers many possible combinations of treatments and program years.

To bring an order to the selection of candidate treatments, the prioritization program uses decision trees and matrices.

Figure A–2: Multiple alternatives evaluated during multi-year analysis and prioritization



A.3 Prediction of the Pavement Condition Immediately After a Treatment Is Applied

The same treatment, applied to the same pavement, but during a different program year will achieve different results. For example, a thin overlay applied to a pavement in good condition may produce better results than when applied to the same pavement years later. Thus, the prediction process must estimate the condition of the pavement immediately after the (predicted) treatment is applied.

A.4 Performance Prediction of the New Treatment

Performance prediction of the new treatment is typically done by assuming an average expected performance. It is done after the performance prediction of the existing pavement, the selection of the new treatment, and the prediction of its immediate effectiveness are completed.

A.5 Summary

The prediction of pavement performance for multi-year prioritization analysis is complex and uses many assumptions. Considerable effort is required to develop and calibrate agency-specific performance prediction models. However, without a judicious prediction of pavement performance, it is not possible to estimate future funding needs reliably.

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Notes

Priority Planning and Budgeting Process for Pavement Maintenance and Rehabilitation

Issue No. 1.0

Publication Date: November 2003