Guidelines for the Implementation of a Pavement Preservation Program for Municipal Pavements in Canada

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ABSTRACT
Preserving municipal pavement infrastructure is paramount to insuring viable transportation of people and goods. It requires increasing investments because of the increasing size of roadway networks and increasing commercial vehicle loading.

Preventive pavement maintenance is important for preserving municipal road infrastructure. Preventive maintenance treatments prevent premature deterioration of the pavement, retard the progression of pavement defects, and cost-effectively extend the life of the pavement. A preventive maintenance treatment is not determined by the type of treatment, but by the reason the treatment is performed.

For cost-effective preventive maintenance it is necessary to apply the right treatment to the right pavement at the right time. The objective is to identify the pavement sections that would benefit most from preventive maintenance, make the identification in a timely manner and select the most beneficial treatment.

The development and implementation of a preventive maintenance program often requires substantial management and technical changes. It should be done in a collaborative manner and should be supported by training and educational activities. To succeed, a preventive maintenance program requires a long-term commitment, ongoing improvements and the documentation and reporting of program benefits.

This paper outlines eight basic steps involved in developing and implementing a pavement preservation program for a municipal agency to apply and evaluate the success of pavement preservation treatments.

KEYWORDS
Preventive maintenance, cost-effective, pavement preservation program, municipal pavements.

INTRODUCTION
Municipal and other owners of pavement networks are faced with two basic questions: how much money is needed for the upkeep of the network, and how can we ensure that money goes where it is most needed? The priority planning and budgeting process described in this paper provides basic guidance for answering these questions and follows the principles, objectives and methodology of asset management.
Canada’s more than 4,000 municipalities are responsible for the management of approximately 750,000 two-lane-equivalent kilometres (465,000 miles) of public roads—not including local streets—ranging from multi-lane expressways to two-lane gravel roads. These represent more than 70 percent of all Canadian roads.

To assist municipalities and other infrastructure owners with the management of municipal infrastructure, including the pavement infrastructure, Infrastructure Canada and the National Research Council (NRC) have provided financial support for the development of the National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices (InfraGuide). The InfraGuide is a Canadian national network of practitioners and collection of documents on best practices for all major components of municipal infrastructure, including roads, potable water distribution systems, sewers and transit systems. The objective of the InfraGuide is to provide a single authoritative reference for infrastructure preservation, including decision-making and investment planning tools and environment protocols, as well as a compendium of technical best practices.

**PRIORITY PLANNING AND BUDGETING**

Every Canadian municipality prepares a budget to preserve pavements, and every municipality has some sort of planning that precedes budgeting (Muntz, 1994). The objectives of the process are (a) to establish the amount of money available or needed and (b) to decide on the best way to invest the money in the pavement infrastructure. The quality of the planning and budgeting process has 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 Pavement Design and Management Guide developed by the Transportation Association of Canada (TAC, 1997) and 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.

Priority planning and programming balances the needs and interests of different audiences (e.g., strategic overview for decision makers and operational detail for technical personnel). It concentrates on the description of the establishment of the level of service, 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 priority planning and budgeting process should be used in conjunction with other asset management tools and best practices dealing with the management of infrastructure needs.

**DECISION FRAMEWORK**

Decision-making for pavement maintenance 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, as illustrated in Figure 1.
Step 1 involves reviewing or establishing the levels of service regarding pavement condition. This activity takes into account a number of factors, such as customer preferences, strategic directions, financial resources and the condition of the pavement network.

Step 2 is to establish a pavement inventory. Every agency 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 traveling public and to improve implementation efficiency.

These first five steps represent network-level management activities, as shown on the right side of Figure 1. The objective of these activities is to ensure that the right pavement sections receive treatment at the right time. Steps 6 through 8 represent project-level activities that ensure that these pavement 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, provides feedback on how the process is working.
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 municipality expected or mandated to provide? Many agencies strive to preserve pavements at the current condition or current level of service.

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.

Figure 2 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.

Indicators and benchmarks are used to translate strategic directions into measures required for infrastructure planning and decision making. 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. A city or municipal council should review and approve the policies on levels of service used by a road department. This way, all subsequent pavement preservation needs are derived from, and are mandated by, the approved levels of service.

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, 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 type or 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 2. The levels of service established for different priority levels also can be used to determine prioritized needs.
Figure 3 shows, as an example, characteristic types of levels of service and trigger values used in pavement management. Minimum safety-related levels of service typically are 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 cm² (96 in²) in area and 8 cm (3.2 in) 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 more significant rehabilitation to meet minimum safety levels of service. Minimum or mandatory levels of service also are called service standards.

The minimum acceptable level of service is the minimum condition for individual pavement sections. 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 usually are 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 that categorize the Pavement Condition Index (on a scale from 0 to 100, where 100 represents a new pavement) of 50 to 70 for overlays, 30 to 50 for partial reconstruction, and <30 for total reconstruction.

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 the maximum percentage of arterial roadways in “poor” condition (e.g., below 40) should be less than 10 percent.

**Pavement Inventory (Step 2)**

Pavement inventory is the key building block for pavement decision-making. The inventory must include the description (size and type) of pavement assets as well as their current and future condition.
Inventory Data

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

Current trends in the storage and display of inventory data include automated mapping, geographical information systems, and video data. Lee and Deighton (1995) developed a mapping system that can display various infrastructure data, such as pavement or water main data, on a common map. The Federal Highway Administration (FHWA, 2001) developed the *Data Integration Primer* that explains principles and options for developing integrated databases.

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 treatments
- A description of the original pavement structure and the subsequent pavement preservation treatments
- Pavement condition (past and current)
- Traffic data (e.g., estimated annual average daily traffic and the percentage of commercial vehicles)

Condition Evaluation

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

To identify maintenance needs, particularly preventive maintenance needs, the condition evaluation must be timely (usually annual or biennial) and detailed. The condition evaluation requires the identification of individual pavement defects, such as transverse cracks, and the evaluation of their severity and extent. The purpose of the condition evaluation completed in this manner is to identify the most effective preventive maintenance treatment at the least cost.

Monitoring of the health of the pavement network must be objective and repeatable to produce true trends. It typically involves the 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. Agencies typically use a pavement quality index that combines the influence of roughness, distresses and structural adequacy. Network condition should be monitored about every second year for high traffic volume facilities and about every third year for local roads and streets.

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.

Figure 4 shows the importance of pavement performance prediction. The present condition rating of the two pavements shown in Figure 4 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 also can be used as one of the factors to prioritize and select candidate sections for treatment.
Long-term predictions (for five or more years) involve how long the existing pavements will last before they require a treatment, as well as how the individual sections will be addressed during the intervening years, and how these treatments will perform.

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

The identification and prioritization of needs for larger municipalities cannot be accomplished effectively 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.

Two types of needs identification are described in the InfraGuide:
- Short-term identification of needs for periods less than about five years
- Multi-year identification of needs for time horizons of about five years or more

**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 5 shows the connection between the level of service, identification of needs, prioritization and budgeting for short-term planning and prioritization.
The following step-by-step description of identification of needs represents a typical process. The process combines all pavement preservation needs together (maintenance as well as rehabilitation treatments). Although some municipalities prepare separate budgets for maintenance (operating) and rehabilitation (capital) work, perhaps for administrative reasons, for cost efficiency and technical reasons it is preferable to have only one integrated process for the identification and prioritization of all pavement preservation needs.

A decision must be made as to what types of treatment should be included in the needs. In general, all roadway maintenance 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, thin, non-structural asphalt concrete overlays and full-depth repairs of Portland cement concrete pavements.

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. The candidate treatments can be identified using engineering judgment, agency-specific guidelines and decision trees, and general guidelines.

The best treatment for the given section is selected. Typically, the selected treatment is generic (e.g., thin-lift overlay), particularly if the treatment is selected by software. Treatment selection must be realistic and must consider the appropriate levels of service. It is important to realize that the identification of needs is not a creation of a wish list, but a documentation of true needs based on approved and mandated standards and levels of service.

Each section, and its recommended treatment, is 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 the treatment is recommended for implementation. One of the following priority categories 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 important to achieve cost-effectiveness)
D. Projects are initiated to achieve a target level of service

The individual treatments are sorted by the category levels (A to D) and by roadway classes. The resulting list represents the total documented and mandated needs for the preservation of the road system.

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 typically are considered mandatory and are not prioritized. The same applies to carry-over projects that need to be completed and already approved projects.

There are many ways to prioritize projects. The priority categories, together with roadway classes, already convey basic priorities. Thus, projects that belong to priority category B (minimum acceptable level of service) and apply to expressways may have higher priority category than projects that belong to priority category D (target levels of service) and apply to residential streets. It is easier and preferable to prioritize projects that belong to the same priority category 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
- Cost-effectiveness (benefit-cost ratio)

Multi-Year Identification of Needs and Prioritization

Multi-year prioritization analysis can consider several treatment options in each analysis year (FHWA, 1997). 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.

Multi-year planning also improves engineering and economic decision-making, because it enables the agency to evaluate the long-term impact 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.

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, Smith & Grogg, 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 a 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.

The candidate projects included in multi-year analysis also should 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.

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 6, 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 2013.

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
- 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 also must consider many other funding needs and programming considerations.
**Budgeting (Step 5)**

Selecting 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 and sewers). The efficient allocation of resources, and the ability to evaluate the consequences of different budget allocations, is a principal premise of asset management.

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 7.

![Figure 7. Budgeting as a combination of technical and financial decisions](image)

A municipal budget consists of many line items. Some municipalities have separate budget entries 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.

**Programming and Budgeting**

The primary budgeting activities are illustrated schematically in Figure 8. Programming and packaging of projects must take into account the following needs and considerations:

- Prioritized pavement preservation needs
- Other roadway needs, including other roadway components (e.g., culverts, bridges and sidewalks), operational improvements (e.g., widening at an intersection and system expansion) and safety improvements
- System operation, including staging projects to minimize inconvenience to the public and advancing projects because of new residential and industrial development
- Related projects, such as work on underground utilities, which should be coordinated to minimize disruption to the public
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 Figure 6
- 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, such as long-term trends in terms of network size, network condition and annual spending per square metre of pavement

![Figure 8. Key budgeting activities](image)

**Project Design and Implementation (Steps 6 and 7)**

The priority planning and budgeting process determines which sections should receive pavement preservation treatments and during which year, the general type of 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. 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.

Over the years, many agencies have developed various technical design aids, such as pavement design and rehabilitation procedures, manuals, specifications and guidelines. 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 Canadian municipalities use one- to three-year warranties for “thin” paving jobs and up to five-year warranties for rehabilitation and reconstruction work.

**Performance Monitoring (Step 8)**

Periodic pavement performance monitoring is important both for individual projects and for the entire pavement network. For example, agencies periodically evaluate past pavement preservation treatments, particularly treatments that are new or experimental. 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.

**IMPLEMENTATION**

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 all stakeholders, including roadway users, local residents and the agency. Support by council – Acceptance and support by the 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 typically is 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.

**CONCLUSIONS**

The process outlined in this paper 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 implication 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.

The use of this process can provide the municipality with specific products, 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 and projects, section-by-section, for budgeting considerations (a budget plan)
• Trends in the condition of the pavement network
• A summary of unmet needs (infrastructure deficit) in terms of specific projects

REFERENCES


